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ABSTRACT

This electricity/electronics guide provides teachers with learning activities for secondary students. Introductory materials include an instructional planning outline and worksheet, an outline of essential elements, a list of objectives, a course description, and a content outline. The guide contains 35 modules on the following topics: electrical energy and work; general safety and the electronics lab; wiring light fixtures and receptacles; wiring a fixture and two three-way switches; a soft drink circuit; semiconductor junction diode characteristics; half-wave rectifier characteristics; full-wave rectifier characteristics; bridge rectifier characteristics; full-wave voltage doubler characteristics; the A-BUS; electronic components; binary to decimal numbers (computer); number conversions; seven-segment display; thermistors and temperature; computer-controlled traffic lights; electronic Etch-A-Sketch; light-intensity sensor; programmable logic controllers; stepper motors; catalog pricing; digital dice; printed circuit boards; electric motors; volt-ohm-milliammeter that measure voltage; electric meters; electrical use logs; semiconductors; resistor color code/ohmmeter familiarization; AC-DC waveform/oscilloscope familiarization; Ohm's law; series resistive circuits; parallel resistive circuits; and electronic schematics. Each module includes an instructor's resource sheet and the student laboratory activity. Each instructor's resource sheet may include the following elements: module number; activity topic; estimated time; essential elements; objectives; activity summary; teaching tips; instructional strategy; equipment/supplies; evaluation key; and support materials. Each student activity may include the following elements: module number; activity topic; activity overview; objectives; vocabulary/concepts reinforced; equipment/supplies; introduction; procedure; evaluation; and support materials. (NLA)

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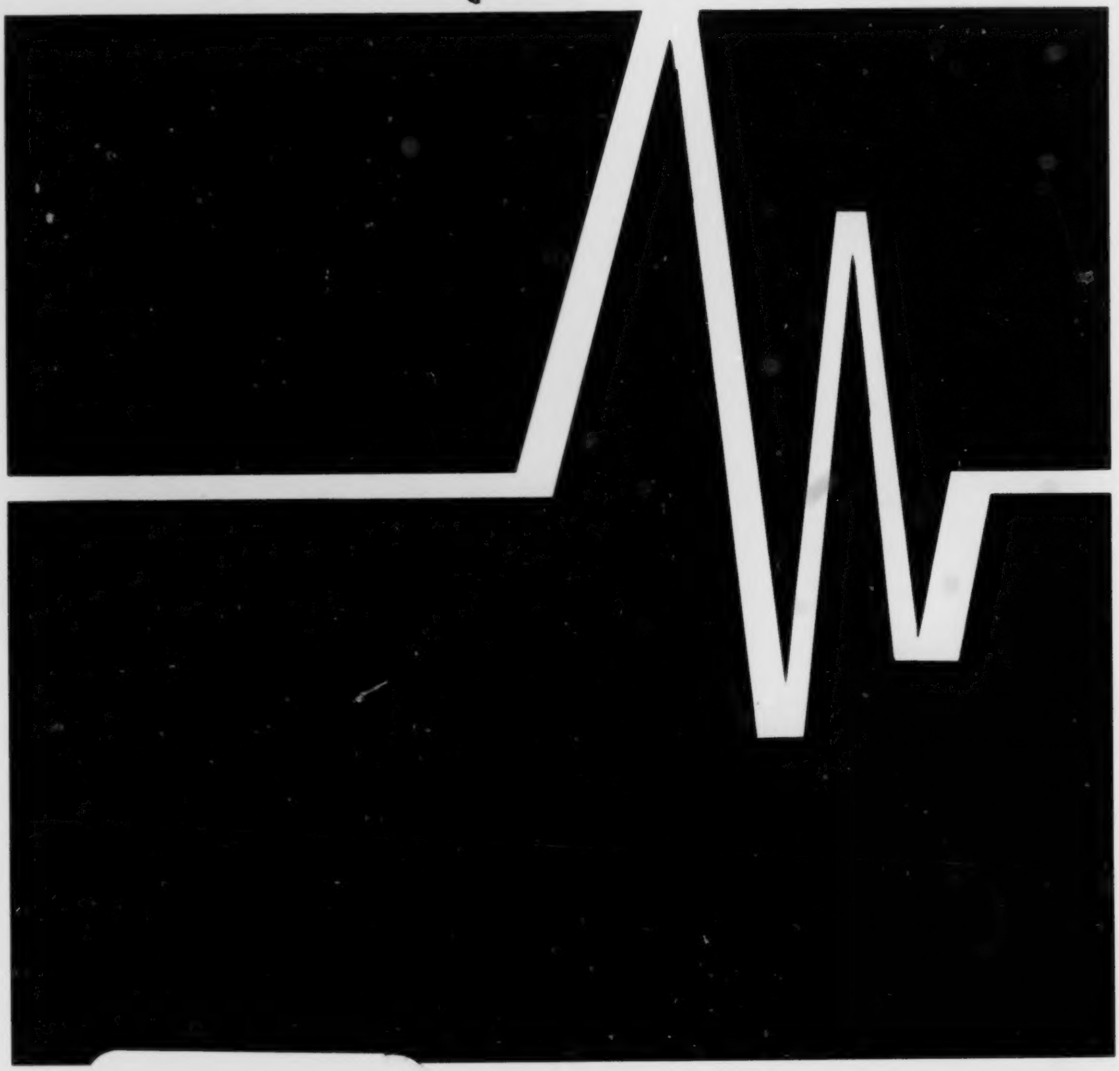
# Electricity/Electronics Systems



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# Electricity/Electronics Systems

## Laboratory Activities

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**Published by**

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# Organization of the Laboratory Activity Materials

The major portion of the guide is the compilation of laboratory activity modules. The laboratory activity modules were developed, tested, and reviewed by technology teachers, supervisors, and teacher educators.

Each module includes (1) the student laboratory activity and (2) an instructor's resource sheet.

Each student activity includes the following elements where appropriate:

- Student activity module number
- Activity topic
- Activity overview
- Objectives
- Vocabulary/Concepts Reinforced
- Equipment/Supplies
- Introduction (to the activity)
- Procedure (step by step)
- Evaluation
- Support Materials

Each instructor's resource sheet includes the following elements where appropriate:

- Instructor's resource sheet module number
- Activity topic
- Estimated time
- Essential Elements (common and specific)
- TAAS Objectives
- Activity Summary
- Teaching Tips
- Instructional Strategy
- Equipment/Supplies
- Evaluation Key
- Support Materials

# Using the Laboratory Activity Materials

**Intended Audience**: The material in this guide is designed for use by technology teachers and students in grades nine through twelve. Many of the modules, however, would also be appropriate and recommended for use by junior high/middle school technology programs.

**Length of Time for the Materials**: The topic of study has been developed to provide materials for 18 to 36 weeks of study. Each module includes a suggested time frame for completion of the activity/module.

**Benefits for Teachers and Students**: The materials included in this guide were developed to assist technology teachers in planning, organizing, teaching, implementing, and evaluating a technology-based instructional program. The broad exposure students will receive by being involved in the laboratory activities in this guide will enhance their total educational program experience including their problem-solving skills, creative thinking skills, and social interaction skills, as well as communication, computation, and technical skills.

**Flexibility of the Materials**: This guide, like other curriculum materials, does not attempt to encompass all situations. Therefore, teachers should supplement the guide with other appropriate ideas, information, and activities as needed in their particular programs.

A key feature in this guide is flexibility. The material may be used in the context of a large class/group approach, a small group approach, where appropriate, and, in many of the modules, an individualized approach. In some of the modules, a combination of all three approaches might be incorporated.

Modules should be selected by teachers in the order that they choose, and teachers are encouraged to expand or condense the student laboratory activity to meet the needs of addressing essential elements and the time frame designated to cover the topic. Teachers may also need to make substitutions in the use of each modules, depending on the equipment, resources, and/or reference materials available to them.

**Essential Elements/TAAS Objectives**: Essential elements and TAAS objectives for reading, writing, and mathematics have been identified in each module (where appropriate). As used in this guide, essential element statements represent skills, knowledge, and/or attitudes that imply the ability or intelligence to accomplish an idea, problem, task, job, etc. Essential element statements will assist the teacher in clearly formulating the scope and sequence of the course of study and the purpose and processes for student learning.

**Instructional Planning**: An instructional planning outline and worksheet are included in the guide for teachers to use in their planning and preparation. The outline and worksheet should prove beneficial to teachers in enhancing their use of various instructional practices, in identifying appropriate teaching behaviors and process decisions, and in documenting teaching techniques selected.

# An Instructional Strategy Approach

Recently the state of Texas revised its long-standing Industrial Arts curriculum to meet the needs of students in a rapidly changing technical society. One of these mandated changes establishes the Electricity/Electronics Systems course. This new course is intended to provide industrial technology education with a broad-based instructional program relating to the various applications of electrical energy and electronics to serve the needs of society. Within the electricity component, students focus on the characteristics, storage, distribution and application of electrical energy. In the electronics component, students focus on the design, production, and application of electronic devices and circuits. Each of these areas uses a number of activities which are guided by the essential elements established for the course.

The teachers involved in this course will probably come from the ranks of the traditional Industrial Arts programs. Many teachers will have made the transition into the other new courses by the time Electricity/Electronics Systems comes on line. The intent of this new course is not to replace existing electronics programs but to establish a new broad-based course from which to develop greater understanding of the electronics and electrical systems used in industry. Instructors will be encouraged to keep the course as activity-based as possible and to make use of equipment such as electrical testing equipment, electronic communication equipment, printed circuit board fabrication equipment, computer hardware and software, as well as laser and fiber optics equipment.

## Setting the Stage

Instructors involved in this new course will realize the great potential that Electricity/Electronics Systems has in presenting both current and emerging technology in the area of electronics and electricity. It will provide an avenue for students interested in these areas to expand their knowledge through a series of fun learning activities. Coupled with the emerging technologies are the many energy conservation and ecological issues that face our society.

The Electricity/Electronics Systems course has the potential of becoming a very strong industrial technology program. If approached correctly, this course should attract students who have typically not participated in our classes for one reason or another. It may be the type of course that will help develop or attract academically oriented students for the Principles of Technology program.

## Instructional Strategies

In developing the preliminary material for this laboratory activity guide, several approaches were considered. The one primary concept that we felt should carry through much of the guide is that of *problem solving*. Problem solving brings the element of critical thinking into our instructional program and challenges students at all levels to develop skills that will last a lifetime no matter how rapidly technology changes. Problem solving through critical thinking may very well be the most important element that we can teach to our students in the next decade.

Another instructional strategy that will be important for industrial technology teachers in the coming years is that of *teamwork*. Teamwork is a central element in all areas of electronics technology and will prove to be an important component of the Electricity/Electronics Systems course. Several of the activities within this guide use this teamwork approach.

As you read through the laboratory activity guide, you will see other more traditional instructional methods. Instructor demonstrations will continue to be one of the most important strategies used throughout the program. Instructor lectures and class discussions will continue to be a necessary component of your instruction. The hands-on student project will perhaps take on a few new dimensions but will continue to play an important role. Our intent is to keep the course as action-based as possible and to make it a fun experience for students.

### Strategies for Special Needs Students

Traditionally, industrial technology education instructors have been receptive to including special needs students in their programs. Students with hearing, visual, and other physical handicaps; learning and behavioral disorders; gifted and talented; and those with slow and retarded learning disabilities have all benefited from the attention given them by interested industrial technology education instructors. This attitude should continue to be a part of our program.

Now that we are entering a new era in which our instructional base is becoming more theoretical and more technological, the special needs students must not be left behind. Our transition into the new curriculum areas is happening at a time when mainstreaming of special needs students is on the increase. As you prepare lessons for the Electricity/Electronics Systems course, remember that your program continues to provide individual learning activities that—

1. use concrete learning versus abstract learning;
2. provide visual instruction;
3. continue to provide much needed hands-on experiences; and
4. provide time for individual instruction.

Take advantage of the resources available on your local campus, as well as those within the school district or community. One of the most effective resources available to teachers is the use of peer tutoring in the classroom. Also, seek the help of resource teachers to help plan or modify existing learning activities. Contact community agencies to find adult aides who might be available to help students on a one-to-one basis.

In using this laboratory activity guide for instructional planning, consider each activity as a beginning point from which to expand. All of the activities can be modified to meet the needs of most special needs students. Consider the following list of modifications as you look for various activities for use with students.

1. Use both visual and verbal instruction.
2. Make use of modeling or simulation.
3. Include thorough demonstration processes.
4. Provide immediate feedback and positive reinforcement.
5. Organize instruction to guarantee success for special needs students.
6. Use sequential steps in processes that are not overly complex, and provide for repetition as needed.
7. Use real-life examples in instruction to help reinforce the importance of the learning activity.

# Instructional Planning Outline

## Domain I. Instructional Strategies

**Criterion 1. Provides opportunities for students to participate actively and successfully**

Indicator:
- a. appropriately varies activities
- b. interacts with students in group formats as appropriate
- c. solicits student participation
- d. extends students' responses/contributions
- e. provides ample time for students to respond to teacher questions/solicitations and to consider content as it is presented
- f. implements instruction an appropriate level of difficulty

**Criterion 2. Evaluates and provides feedback on student progress during instruction**

Indicator:
- a. communicates learning expectations
- b. monitors students' performances as they engage in learning activities
- c. solicits responses or demonstrations from specific students for assessment purposes
- d. reinforces correct responses
- e. provides corrective feedback, or none needed
- f. reteaches, or none needed

## Domain II. Classroom Management and Organization

**Criterion 3. Organizes materials and students**

Indicator:
- a. secures student attention, or students are attending
- b. uses administrative procedures and routines which facilitate instruction
- c. gives clear administrative directions for classroom procedures or routines, or none needed
- d. maintains seating arrangements/grouping appropriate for the activity and the environment
- e. has materials, aids, and facilities ready for use

**Criterion 4. Maximizes amount of time available for instruction**

Indicator:
- a. begins promptly/avoids wasting time at the end of the instructional period
- b. implements appropriate sequence of activities
- c. maintains appropriate pace
- d. maintains focus
- e. keeps students engaged

**Criterion 5. Manages student behavior**

Indicator:
- a. specifies expectations for class behavior, or none needed
- b. uses techniques to prevent off-task behavior, or none needed
- c. uses techniques to redirect off-task behavior, or none needed
- d. uses techniques to stop inappropriate behavior, or none needed
- e. uses techniques to stop disruptive behavior, or none needed
- f. applies rules consistently and fairly
- g. reinforces appropriate behavior when appropriate

## Domain III. Presentation of Subject Matter

### Criterion 6. Teaches for cognitive, affective, and/or psychomotor learning and transfer

Indicator: a. begins instruction/activity with an appropriate introduction
b. presents information in an appropriate sequence
c. relates lesson content to prior or future learning
d. provides for definition of concepts and description of skills and/or attitudes and interests
e. provides for elaboration of critical attributes of concepts, psychomotor skills, and/or attitudes and interests
f. stresses generalization, principle, or rule as a relationship between or among concepts, skills, and/or attitudes/interests
g. provides opportunities for transfer
h. closes instruction appropriately

### Criterion 7. Presents information accurately and clearly

Indicator: a. makes no significant errors
b. uses vocabulary appropriate to students
c. explains content and/or learning tasks clearly
d. stresses important points and dimensions of content
e. clarifies student misunderstanding, or none needed

### Criterion 8. Uses acceptable communication skills

Indicator: a. uses correct grammar
b. pronounces words correctly and clearly
c. uses accurate language
d. demonstrates skill in written communication

## Domain IV. Learning Environment

### Criterion 9. Uses strategies to motivate students for learning

Indicator: a. relates content to student interests/experiences
b. emphasizes the value/importance of the activity or content
c. reinforces learning efforts of students
d. challenges students

### Criterion 10. Maintains supportive environment

Indicator: a. avoids sarcasm and negative criticism
b. establishes climate of courtesy and respect
c. encourages slow and reluctant students
d. provides praise for specific performance
e. establishes and maintains positive rapport with students

## Domain V. Growth and Responsibilities

### Criterion 11. Plans for and engages in professional development

Indicator: a. shows progress in completing professional growth requirements as agreed upon with appraiser(s), or none needed
b. stays current in content taught
c. stays current in instructional methodology

**Criterion 12. Interacts and communicates effectively with parents**

Indicator: a. initiates communications with parents about student performance and/or behavior when appropriate
b. conducts parent-teacher conferences in accordance with local district policy
c. reports student progress to parents in accordance with local district policy
d. maintains confidentiality unless disclosure is required by law

**Criterion 13. Complies with policies, operating procedures, and requirements**

Indicator: a. follows statutory and Texas Education Agency regulations
b. follows district and campus policies and procedures
c. performs assigned professional duties
d. follows district promotion/retention policy and procedures

**Criterion 14. Promotes and evaluates student growth**

Indicator: a. participates in campus goal-setting for student progress
b. plans instruction in accordance with district requirements
c. documents students progress
d. maintains accurate records
e. reports student progress at appropriate intervals

# Instructional Planning Worksheet

**Essential Element(s):**______________________________
**TAAS Objective(s):** ______________________________
**Curriculum Guide Page:**______________________________

**Objective:** At the conclusion of the lesson, the learner will be able to:

______________________________
______________________________
______________________________
______________________________

**Focus Activity:**______________________________
______________________________
______________________________

a. Task for lesson______________________________
______________________________

b. Value of lesson to learner is______________________________
______________________________

**Explanation / Check Understanding:**

a. ☐ Lecture ☐ Overhead ☐ Demonstration ☐ ____________
b. ☐ Curriculum Guide page _____ ☐ Text page _____ ☐ ____________
c. Modeling (teaching will)______________________________
______________________________
______________________________
d. Key questions to check understanding:
1.______________________________
2.______________________________
3.______________________________
4.______________________________
5.______________________________
6.______________________________

**Guided Practice Exercise:**

☐ Exercise copied from overhead ☐ Handout worksheet No.______________

☐ Copy from board ☐ Read sample problems ☐ ____________________

________________________________________

________________________________________

**Checking Mastery (Learning Progress)**

☐ View each student's work ☐ Students check and signal correct

☐ ________________________________________

________________________________________

**Independent Practice:** (Reteach those needing help while others work)

☐ Worksheet No.________ ☐ Copy from overhead ☐ Copy from board

☐ Copy as dictated ☐ Reteach worksheet/outline number ______________

☐ ________________________________________

☐ ________________________________________

**Extension:** (Enrichment/Application)

☐ Worksheet No._______ ☐ ____________________________

Describe how this activity makes relevant application of the lesson: ________________

________________________________________

________________________________________

________________________________________

**Closure:** Restate the learning: ____________________________

________________________________________

Method to involve the learner in the summary: ______________________

________________________________________

**Sponge Activities:** Sponge Focus Activity No. ____________________

Other Sponge Activity No. ______________________________

# Essential Elements
# Common to All Industrial Technology Programs

**75.85** The elements in this subsection are common to all industrial technology education courses unless otherwise indicated and shall be included in each course at the appropriate level. They are described here to preclude repetition in each course. Every school offering industrial technology education shall provide courses which include the following essential elements.

1. Leadership concepts and skills. The student shall be provided opportunities to:

    A. demonstrate skills, characteristics, and responsibilities of leaders and effective group members;
    B. demonstrate a knowledge of parliamentary procedure principles;
    C. plan and conduct leadership activities; and
    D. prepare for effective citizenship and for participation in our democratic society.

2. Concepts and skills related to successful employment and/or postsecondary training. The student shall be provided opportunities to:

    A. identify employment opportunities and preparation requirements in chosen fields;
    B. identify effective methods to secure and terminate employment;
    C. demonstrate effective communication skills both oral and written and follow through on assigned tasks;
    D. demonstrate dependability and punctuality;
    E. demonstrate productive work habits and attitudes;
    F. understand the importance of taking pride in the quality of work performed;
    G. recognize the dignity in work;
    H. develop skills in planning and organizing work;
    I. apply required methods and sequences when performing tasks;
    J. apply principles of time management and work simplification when performing assigned tasks;
    K. identify ethical practices and responsibilities; and
    L. understand the importance of the application of organizational policies and procedures.

3. Concepts and skills associated with entrepreneurship. The student shall be provided opportunities to:

    A. identify opportunities for business ownership;
    B. understand the risk and profit motive factor;
    C. understand the elements and advantages of the free enterprise system; and
    D. explain the role of small business in the free enterprise system.

4. Concepts and skills associated with human relations and personality development. The student shall be provided opportunities to:

    A. understand the importance of maintaining good health and proper appearance for effective job performance;
    B. understand oneself and others;
    C. exercise self-control;

D. accept and use criticism;
E. recognize basic human relationship as they relate to business success; and
F. demonstrate characteristics for successful working relationships.

5. Concepts and skills related to personal and business management. The student shall be provided opportunities to:

   A. explain how management assists in reaching personal and family goals;
   B. explain the management process;
   C. describe the role of management in controlling stress;
   D. identify and understand personal checking accounts;
   E. identify and understand personal loan application processes;
   F. identify and understand different financial institutions;
   G. identify the role and functions of business management;
   H. understand the lines of authority; and
   I. identify effective supervisory techniques.

6. Concepts and skills related to the application of safety practices. The student shall be provided opportunities to:

   A. demonstrate safe operation of appropriate tools, machines, and equipment;
   B. maintain a safe and clean laboratory environment; and
   C. investigate appropriate state and federal safety laws.

7. Concepts and skills related to social/cultural impacts of technology. The student shall be provided opportunities to:

   A. investigate ideas and technological developments of the past and present;
   B. assess the characteristics of technological change on society and culture;
   C. predict how selected technological developments will impact future cultures and societies; and
   D. explore the impact technology has on the environment.

8. Concepts and skills related to the application of technology to daily life. The student shall be provided opportunities to:

   A. evaluate selected products based on given standards or applications;
   B. develop criteria for selecting, purchasing, and contracting services;
   C. practice the servicing of selected products and equipment of technology;
   D. investigate the interrelationship of all technology areas;
   E. use computer-controlled systems and/or devices related to each course; and
   F. apply the design process to product development.

9. Concepts and skills related to the tools, materials, and processes of technology. The student shall be provided opportunities:

   A. become proficient in the use of appropriate tools, machines, and equipment;
   B. analyze the properties of a wide range of materials of technology through testing;
   C. explore the processes of various technologies; and
   D. investigate and practice conservation and recycling of products and materials of technology.

10. Concepts and skills related to the application of problem-solving techniques. The student shall be provided opportunities to:

    A. identify and creatively solve technological problems using the scientific method;
    B. explore standards of measurement used in technology and apply measurement in the solution of problems; and
    C. communicate oral, written, and computational technical information.

# Electricity/Electronics Systems Essential Elements

Electricity/electronics systems, 11601302, EES (1/2-1 unit). Electricity/electronics systems is a laboratory-oriented course that includes the common essential elements for industrial technology education, plus concepts and skills related to electricity/electronics systems. The student shall be provided opportunities to:

1. investigate AC/DC electrical current and voltage;
2. recognize the relationship between electrical energy and work;
3. recognize the properties of conductors, insulators, and semiconductors;
4. investigate solar cells, fuel cells, and other alternative sources;
5. assess power generation and distribution of electricity by public utilities;
6. explore magnetic field theory and static electrical charges;
7. apply the National Electrical Code and its local variations;
8. investigate DC motors, generators, alternators, and transformers;
9. examine resistive components, capacitors, and inductors;
10. recognize the properties of N-type and P-type semiconductors;
11. analyze opto-electronic components and lasers;
12. compare the various types of integrated circuits;
13. recognize binary and hexadecimal numbering systems;
14. analyze the application of analog and digital components to computers;
15. explore radio, television, telephone systems, and fiber optics; and
16. investigate space-based information services through satellite systems.

# Texas Assessment of Academic Skills (TAAS): Domains and Objectives

## ENGLISH LANGUAGE ARTS
## GRADES 3, 5, 7, 9 AND EXIT LEVEL

DOMAIN: *READING COMPREHENSION*

OBJECTIVES:

The student will:

1. determine the meaning of words
2. identify supporting ideas
3. summarize written texts
4. perceive relationships and recognize outcomes
5. analyze information to make inferences/generalizations
6. recognize points of view, propaganda, and/or fact and nonfact

DOMAIN: *WRITTEN COMMUNICATION*

OBJECTIVES:

The student will:

1. respond appropriately to the purpose/audience in a written composition
2. organize ideas in a written composition
3. demonstrate control of the English language in a written composition
4. generate a written composition which develops and supports a central idea
5. recognize appropriate sentence construction
6. recognize appropriate word usage
7. recognize within the context of a written passage:
   (a) the correct spelling of words
   (b) correct capitalization
   (c) appropriate punctuation

# MATHEMATICS
## GRADES 3, 5, 7, 9, AND EXIT LEVEL

DOMAIN: *CONCEPTS*

OBJECTIVES:

The student will:

1. demonstrate an understanding of the concepts of numbers
2. demonstrate an understanding of mathematical relations, functions, and other algebraic concepts
3. demonstrate an understanding of geometric properties and relationships
4. demonstrate an understanding of measurement concepts using metric and customary units
5. demonstrate concepts related to an understanding of probability and statistics

DOMAIN: *OPERATIONS*

OBJECTIVES:

The student will:

1. demonstrate skills, concepts, and applications related to addition
2. demonstrate skills, concepts, and applications related to subtraction
3. demonstrate skills, concepts, and applications related to multiplication
4. demonstrate skills, concepts, and applications related to division

DOMAIN: *PROBLEM SOLVING*

OBJECTIVES:

The student will:

1. estimate solutions
2. analyze problems and identify solution strategies
3. express problems using mathematical representations
4. evaluate the reasonableness of problem solutions

# Electricity/Electronics Systems
# Course Description and Content Outline

*Grades 9-12, 1/2-1 unit*

Electricity/Electronics Systems is an activity-based course introducing students to the concepts and application of electrical energy and electronics to serve the needs of this society. In the electricity component, students focus on the generation, characteristics, storage, distribution, and application of electrical energy. In the electronics component, students focus on the design, production, and application of electronic devices and circuits. Examples of student learning activities are: construct a fuel cell, install a home wiring system according to accepted standards, disassemble and assemble electric motors, fabricate a printed circuit utilizing solid state and/or digital components, design a voice communication system utilizing fiber optics, and develop a research report on the characteristics of electricity. Examples of equipment used are: electrical test equipment, electronic communication equipment, printed circuit board fabrication equipment, computer hardware/software, laser and fiber optic trainers, and general production equipment.

| Essential Elements | Suggested Content Outline | Suggested Learning Activities |
|---|---|---|
| | I. Introduction | |
| | A. Overview | |
| | 1. Electricity/electronics systems | |
| | a. What are electricity/electronics systems? | |
| | b. Why study electricity/electronics systems? | |
| | 2. Career opportunities | Prepare a report on a specific career opportunity in the electronics industry. |
| | a. Occupations | |
| | (1) Electrical engineer | |
| | (2) Electronics technician | |
| | (3) Electrician | |
| | b. Preparation | Prepare a report on the preparation necessary for employment in a specific electronics occupation. |
| | (1) University | |
| | (2) Vocational trade school | |
| | (3) Military | |
| | (4) Apprenticeship | |
| | B. Impact of electricity/electronics systems | |
| | 1. Past | |
| | a. Life without electricity/electronics | Produce a report on early alternatives to electrical energy. |
| | b. Origins of electricity/electronics concepts | |
| | (1) Ancient discoveries | |
| | (2) Electricity in the 19th century | Produce a report on a specific electrical/electronics invention. |
| | (3) Radio and TV (1905-) | |
| | (4) The transistor effect (1947) | |
| | (5) The integrated circuit (≈1960) | |
| | (6) The microprocessor (≈1972) | |

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| 2. Present | |
| a. Use of electricity/electronics systems | Produce a report on a unique application of electricity. |
| b. Economics of electricity/electronics | |
| (1) Electricity production and distribution | Produce a report, presentation, and/or model of an electrical generating facility and distribution network. |
| (2) Electronic components manufacturing | |
| (3) Electronics products manufacturing | Review the variety of products and their specifications as reported in industry trade journals. |
| c. Environmental cost of electrical energy | |
| 3. Future | |
| a. Problems | |
| (1) Long-term impact on the environment | Prepare a report on the environmental impact of one form of fuel used to produce electrical power. |
| (2) Disparity between haves and have-nots | |
| (3) Privacy and information sources | |
| (4) Occupational shift to service economy | |
| b. Promises | |
| (1) Improved standard of living worldwide | |
| (2) Enhanced worldwide communications | |
| (3) Microminiaturization of products | |
| (4) Potential for low-cost electrical energy | |
| C. Interrelationship of technologies | |
| 1. Communication Technology | |
| a. Computer-aided-design/drafting | Produce printed circuit board layout artwork on a CAD system. |
| b. Photography | |
| c. Radio/TV | |
| d. Telecommunications | |
| 2. Production Technology | |
| a. Uses of electrical power | |
| b. Control of manufacturing processes | Use computer software to simulate the industrial requirements for electrical energy. |
| c. Production planning and data storage | Use computer simulation software to plan a production activity. |
| D. Relationship to other disciplines | |
| 1. Mathematical basis of electrical laws | |
| 2. Physics and electronics | Use some of the activities in the *Systems of Technology* package. |
| 3. Communications skills | |
| II. Elements of Electricity/Electronics Systems | |
| A. Tools | |
| 1. Meters | |
| a. Voltmeters | Use a voltmeter to measure the voltage of a number of power sources. |
| b. Ammeters | |

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| c. Wattmeters | Determine the electrical energy consumption and bill for a typical residence. |
| 2. Oscilloscopes | |
| 3. Fabrication tools | |
| a. Power tools | Use a drill press to drill the holes in a printed circuit board. |
| b. Hand tools | |
| c. Soldering irons | Assemble an original circuit board or electronic kit. |
| B. Materials | |
| 1. Components | |
| a. Wire | |
| b. Resistors | Identify the various components in a radio/TV receiver. |
| c. Capacitors | |
| d. Chokes and coils | |
| e. Transformers | |
| f. Motors and generators | Identify the various types of motors in other parts of the laboratory or school building. |
| g. Transistors | |
| h. Integrated circuits | Identify the integrated circuits and solid-state devices in a microcomputer. |
| 2. Fabrication | |
| a. Printed circuit board | |
| b. Cabinets and cases | Construct an electronic case from sheet metal using simple hand brakes and aviation snips. |
| C. Processes | |
| 1. Design and problem solving | Design a unique electrical/electronic circuit to do a specific job. |
| 2. Systems model | |
| a. Input | Determine the required resources in terms of people, materials, etc., needed to produce an electrical/electronics system. |
| (1) People | |
| (2) Materials | |
| (3) Information | |
| (4) Capital | |
| (5) Energy | |
| b. Process | Identify the processes needed to produce a specific electronic or electrical component. |
| (1) Encoding | |
| (2) Transmitting | |
| (3) Receiving | |
| (4) Storing | |
| (5) Retrieving | |
| (6) Decoding | |
| c. Output | Identify the variety of products produced by the electronics industry. |

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| (1) Products | |
| (2) Structures | |
| (3) Relocated objects, people, ideas | |
| (4) Information | |
| d. Feedback | Report the effect of feedback in electronic amplifier circuits and industrial control systems. |
| (1) Positive | |
| (2) Neutral | |
| (3) Negative | |
| 3. Research and development | Solve a unique electrical/electronics problem by designing a device, system, or approach. |
| a. Planning | |
| b. Processes | |
| (1) Schematic design | |
| (2) Component selection | |
| (3) Fabrication methods | |
| 4. Quality | |
| a. Quality control | |
| (1) Test procedures | Investigate the measurement techniques used to ensure the quality of electronics components. |
| (2) Statistical sampling | |
| (3) Underwriters Laboratory | |
| b. Quality assurance | |
| (1) Follow-up | |
| (2) Feedback to production | |
| D. People | Investigate the management of people needed to perform the various steps in electronics construction. |
| 1. Management | |
| 2. Leadership | |
| 3. Entrepreneurship | |
| E. Information | |
| 1. Component specification | Report on the specifications used to determine the uses of a specific electrical/electronics component. |
| 2. Communications electronics | |
| 3. Consumer information | |
| F. Safety | |
| 1. Shock hazards | Provide a basic course in CPR. |
| 2. Hand tools | |
| 3. Soldering | |
| G. Service | |
| 1. Troubleshooting | Troubleshoot a malfunctioning electrical/electronics device. |
| 2. Preventive maintenance | |
| III. Applications of Electricity/Electronics Systems | |
| A. Electrical systems | |
| 1. Character of electricity | Investigate and report the basic characteristics of electricity through laboratory experimentation. |

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| a. Electron theory | |
| b. Electromagnetism | |
| c. Capacitance | |
| d. Inductance | |
| 2. Sources of electrical power | |
| a. Generators/alternators | Construct a simple generator. |
| b. Batteries and fuel cells | Construct a working electrochemical device such as a battery and/or fuel cell. |
| c. Alternate sources | Construct a wind generator using an automobile alternator. |
| 3. Distribution of electrical power | |
| 4. Utilization of electrical power | |
| a. Motors | Investigate and report the characteristics of several types of electric motors through laboratory experimentation. |
| b. Relays and solenoids | Design and construct a relay control system. |
| c. Resistance seating | |
| d. Lighting | |
| 5. Wiring and switching circuits | |
| a. Materials, devices, and tools | |
| b. Circuit layout | |
| c. National/local electrical codes | Install and interconnect a representative home wiring system consisting of a service entrance, breaker panel, appliance outlets, lights, and switches into a wall section according to the appropriate National and/or Local Electrical Code. |
| B. Electronics systems | |
| 1. Solid-state theory | |
| a. Semiconductors | |
| b. P-N junction | |
| c. Field effect | |
| 2. Discrete solid-state devices | Investigate the operation of solid-state devices through laboratory experiment. |
| a. Diodes and thermistors | |
| b. Bipolar transistor | Build a simple transistor amplifier. |
| c. Field effect transistor | |
| d. Thyristors | Construct a device such as a burglar alarm which uses a thyristor such as an SCR or TRIAC. |
| e. Lasers | Use a laser trainer to demonstrate the characteristics of laser light. |
| 3. Integrated circuits | |
| a. Digital logic gates | Use a digital trainer to investigate the basic logic gates. |
| b. Timers | Use a digital trainer to set up a timer/counter system. |
| c. Operational amplifiers | |
| d. Complex functional blocks | |

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| 4. Microprocessor architecture | Use a microprocessor trainer to investigate microcomputer programming and architecture. |
| a. Number systems | |
| b. Functional block diagrams | |
| c. Central processing unit | |
| d. Random access memory | |
| e. Read only memory | |
| f. Peripheral devices | Use a thermistor and computer system to measure temperature. |
| 5. Microprocessor software | Control an input/output interface with a microcomputer. |
| 6. Communications electronics | Construct and/or operate a radio/TV/satellite communications receiver. |
| a. Telephone | |
| b. Radio | |
| c. Television | |
| d. Satellite | Operate a satellite receiver. |
| e. Telecommunications | |
| f. Fiber optics | Set up a voice communication system using a laser, fiber optic cable, and photodiode receiver. |
| C. Electricity/electronics production | |
| 1. The electricity/electronics industry | Report on the number of people and economics of the electrical or some part of the electronics industry. |
| a. Organization | |
| b. Jobs | |
| c. Economics | |
| 2. Manufacturing processes | Design and fabricate a working printed circuit board using solid-state and/or digital components. |
| a. Point to point wiring | |
| b. Printed circuit boards | |
| c. Electronic assembly | Construct a working electric motor. |
| IV. Impacts | |
| A. Consumer | Produce a report on the impact of electronics on the modern consumer. |
| 1. Cost | |
| 2. Efficiency | Monitor and operate a home security and/or appliance control system using a microcomputer. |
| 3. "Saved" labor | |
| B. Environmental | |
| 1. Electronics manufacturing | Report on the toxic materials used to produce printed circuit boards and other electronic components. |
| 2. Electrical generation | |
| 3. Consumer use | |
| C. Social/Cultural | Report on the impact of electricity/electronics on the general |

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| | population of the locality, state, nation, and world. |
| 1. Technological society<br>2. Information glut<br>D. Economic<br>1. Importance of electronics industry<br>2. World electronics production | |
| V. Electricity/Electronics Enterprise<br>1. Organization<br>2. Management<br>3. Labor<br>4. Products<br>5. Services | Organize an electronics manufacturing company, do market research, design a product, and manufacture it. |

# THE RELATIONSHIP BETWEEN ELECTRICAL ENERGY AND WORK

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**Essential Elements:** Common: 6, 8, 9
Specific: 1, 2
**TAAS Objectives:** Language Arts: RC 1-6

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## Activity Summary

This activity is intended to provide teachers with an introductory lesson in the relationship between electrical energy and work. Students will read an introductory section based on the topic and complete an observation experiment using an incandescent light bulb and a dimmer switch.

## Teaching Tips

1. Read through the entire activity, and become familiar with the topic before releasing it to students.
2. Create a display bulletin board related to the topic.

## Instructional Strategy

- Lecture to present the topic to students.
- Use this activity as either a small group or individual project.

## Equipment/Supplies

1. Dimmer switch
2. Light receptacle
3. Incandescent light bulb
4. Necessary wire
5. Receptacle plug
6. Miscellaneous hand tools
7. Flashlight with batteries
8. Electric fan

## Evaluation Key

Instructor evaluation of student performance should be based on participation in and completion of the activity.

# THE RELATIONSHIP BETWEEN ELECTRICAL ENERGY AND WORK

*Observe the effects of electrical current on various devices designed to perform specific types of work.*

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## Objectives

- To develop an understanding of the relationship between electrical energy and its ability to perform work
- To observe a light bulb as it converts electrical energy to heat and light
- To develop an understanding of how an electrical current will create heat in materials that it passes through
- To develop an understanding of the concept that when energy is converted from one form to another, some of that energy is lost in the form of heat

## Vocabulary/Concepts Reinforced

- Incandescence
- Incandescent
- Filament
- Battery

## Equipment/Supplies

- Dimmer switch
- Light receptacle
- Incandescent light bulb (clear)
- Wire
- Receptacle plug
- Flashlight with batteries
- Miscellaneous hand tools
- Electric fan

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## Introduction

Many people feel that a proper definition of energy is the *ability to do work.* Electricity is just one form of energy. The other forms include light energy, heat energy, chemical energy, and the energy of motion. It is difficult to create energy, and only through nuclear fusion can we create energy from matter. Energy, therefore, should be thought of as *changing from one form to another*.

In order to convert energy from one form to another, we usually rely on some type of machine. For example, a car converts the chemical energy present in gasoline into heat energy which in turn converts the mechanics of the car into motion. If the definition of energy is applied to this situation, then the energy conversion in an automobile does, in fact, perform work.

An electrical light bulb performs work in two ways. When an incandescent light bulb is turned on, it produces light and some heat. When a heat lamp is turned on, it produces a lesser amount of light but a great deal of heat. As you can see in this example, the light bulb converts electrical energy into both heat and light. One inherent problem with the typical incandescent light bulb is that it is very inefficient.

In a typical light bulb, only about 4 percent of the electrical energy is converted into light, and the remaining 96 percent is lost to heat.

A filament in the light bulb is what actually performs the lighting function. As electrical energy passes through the filament, the thin wires begin to heat and change color and become brighter. This brightening process is known as incandescence. This is why we call a standard light bulb an incandescent bulb. Study the diagram of the incandescent bulb, and become familiar with its various parts.

Another form of electrical energy at work that you can easily observe is through the workings of a battery-operated flashlight. A battery-operated flashlight uses the chemical energy in the batteries to generate an electrical current, which in turn heats the filament of the light bulb, producing light.

Another machine that we rely on occasionally is an electric fan. The typical electric fan converts electrical energy into motion by means of an electric motor and specially designed fan blades. The typical house fan is a little more efficient than a light bulb and probably converts about 43 percent of the electrical energy into motion. The remaining energy is converted or actually lost in the form of heat. The work performed by the fan through its conversion of electrical energy is fan motion or movement of air to help cool us on a warm day.

**Procedure**
Complete the following work sheet.

1. Set up your incandescent light bulb in the receptacle, and connect the dimmer switch.
2. Allow the light bulb to pop on; then decrease the voltage with the dimmer. As you back off the current, try to make the filament as dim as possible. What color is the filament at this low current level? _________
3. Feel the surface of the bulb. Is it warm or very hot? ________________
4. Now, slowly increase the current by moving the dimmer switch to its maximum setting. Observe what effect this has on the color of the filament. Describe this effect. ___________________________________________
5. With the current at its maximum setting, what is the effect on the amount of heat that is generated? _________________________________________
6. Based on your observation of the incandescent light bulb, what two forms of energy conversion are present when an electrical current is applied to the filament? ________________ and _______________
7. What is the name of the process of heating a filament to produce light?
   _____________________________________

Connect the electric fan to the dimmer switch, or use the speed control on the fan to make the following observations.

8. With the fan at its lowest setting, what effect does the level of current have on the speed of the fan blades? _________________________
9. At this lowest setting, carefully feel the outside housing of the electric motor and observe the temperature. Is the motor hot or warm? _______
10. Increase the current to the fan motor to its highest setting, and observe what happens to the speed of the fan blades. ________________________

11. At this higher setting, carefully feel the motor housing and compare the temperature with that of the lower setting. Is it warmer or cooler?

    ________________________________

12. The electric fan converts electrical energy into two other forms of energy. What are they? ____________________ and ____________________

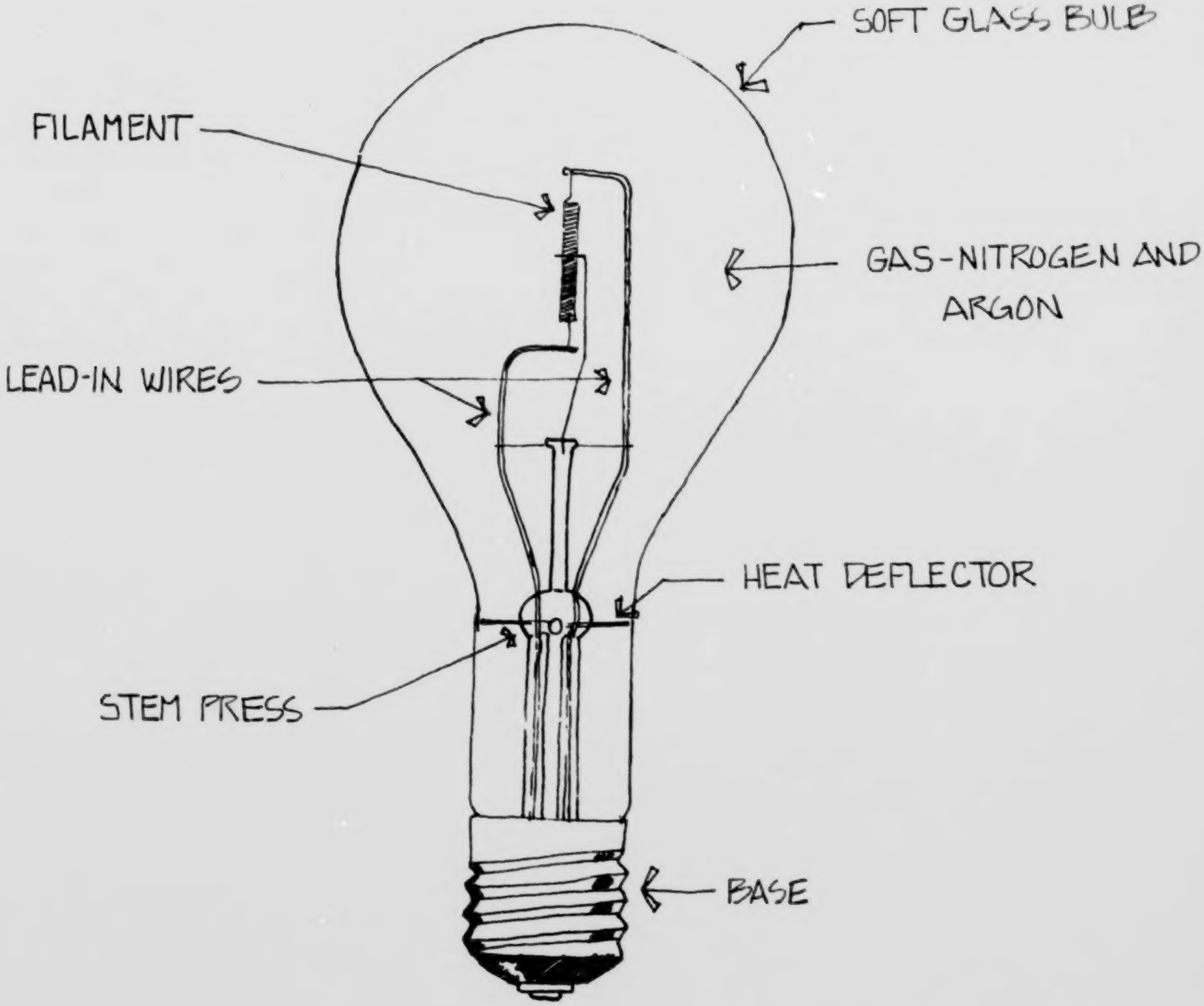
For the following observations use a flashlight that uses batteries.

13. The battery-operated flashlight generates electrical current through which form of energy conversion? ________________________
14. What two forms of energy can be observed as a result of this type of energy conversion? ______________________ and ____________________
15. What is the principal type of work performed by the battery-operated flashlight? ________________________________

**Evaluation**

Instructor evaluation of your performance should be based on participation in and completion of the activity.

# INCANDESCENT LIGHT BULB


SOFT GLASS BULB
FILAMENT
GAS-NITROGEN AND ARGON
LEAD-IN WIRES
HEAT DEFLECTOR
STEM PRESS
BASE

# GENERAL SAFETY IN THE ELECTRONICS LAB

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**Essential Elements:** Common: 6
Specific: 1
**TAAS Objectives:** Language Arts: RC 1-6

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## Activity Summary

This module is designed to provide a basic safety-oriented learning activity based on hazards in the electronics lab and precautions to observe. The emphasis of this module is on the prevention of personal injury and damage to lab equipment. Effective safety procedures are important to the electronics lab technician, who will be exposed to a lifetime of potentially dangerous working conditions.

## Teaching Tips

1. Read through the entire activity before releasing it to students.
2. Prepare a bulletin board display related to electrical safety in the lab area.
3. Use any additional materials that you may have, such as audiovisual overhead transparencies, videotapes, etc.

## Instructional Strategy

- Use this module as an individual learning activity.
- Lecture to present the topic to students.
- Use the demonstration method to illustrate various safety procedures to students.
- Use the Safety Test to help reinforce specific concepts.

## Equipment/Supplies

1. Copies of the Safety Test
2. Miscellaneous demonstration materials as needed

## Evaluation Key

Instructor evaluation of student performance should be based on participation in the activity and completion of the Safety Test.

# GENERAL SAFETY IN THE ELECTRONICS LAB

*Learn the basic safety and first aid procedures for the electronics lab.*

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## Objectives

- To identify the general safety precautions common to the electronics lab
- To describe the effects of electric shock
- To learn how to administer first aid for electric shock

## Vocabulary/Concepts Reinforced

- None

## Equipment/Supplies

- None

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## Introduction

The electronics lab technician is exposed to a wide variety of potentially hazardous conditions on a daily basis. Students working in a school electronics lab will be exposed to many of these same conditions throughout the lab course. It is therefore very important for you to develop a thorough understanding of these potentially dangerous conditions in order to prevent injury to yourself and to others.

Probably the two most important requirements for working in any of the industrial technology lab areas are using common sense and using good judgment. Government regulations have made working conditions as safe as possible, but there is no way to govern personal carelessness and thoughtlessness when working with potentially hazardous equipment and procedures. Statistics show that nearly 85% of all industrial related accidents are caused by personal carelessness and general lack of consideration for others.

### *General Precautions*

1. The most fundamental of all safety precautions is to think through the procedure that you are about to perform. Carelessness and thoughtlessness can result in serious injury as well as damage to equipment. Be alert to what you are about to do.
2. Avoid wearing loose-fitting clothing. Remove any jewelry, such as metal rings, watches, chains, etc., that might come into contact with the equipment that you are working with. Wear shoes with crepe soles, or use a rubber mat to stand on.
3. Carefully read the schematics of any electrical equipment that you are about to work on. If you are not sure about a specific condition, ask your instructor to assist you.
4. Be sure to de-energize all circuits in addition to the main power supply of any equipment that you are about to work on. Do not change parts or make adjustments to equipment with high voltage.
5. Be aware of voltage conditions. Voltages below 50 V are considered low voltages, 50 to 220 V are medium voltages, and voltages above 220 V are considered high voltages. Respect them all. Most electrical deaths are caused by regular household power supplies which are 120 V.

6. Don't work in the lab by yourself. Always work in the presence of another person who is familiar with the equipment and dangers associated with electronic equipment.
7. Never tamper with interlocks. Interlocks are devices designed to break the circuit when access or service panels are removed from some types of electrical equipment. Many television sets, for example, use interlocks on the back service panel to protect service technicians from hot circuits.
8. Be careful not to ground yourself when working on energized circuits or using measuring instruments. Use only one hand when servicing energized equipment, and keep the other hand behind you. By hooking the thumb of your second hand into your back pocket, you will ensure that it will not come into contact with the energized circuit.
9. Do not energize electrical circuits around water. If there is any evidence of moisture or water around electrical equipment, dry it thoroughly before attempting to energize the equipment.
10. Be careful when working with batteries. Some batteries contain acid which can cause burns to the skin and eyes.
11. Cleanliness is important. Always keep work areas clean and neat. Avoid clutter and unnecessary tools and equipment in and around work stations.
12. Use only tools that are approved by your instructor, and use them only for the purpose for which they were intended.
13. Never run or participate in any horseplay activity in the lab area.
14. When lifting heavy objects, be sure to lift from the legs and not from the back.
15. Do not take unnecessary chances. If you do not know what to do, ask for assistance.
16. If there is an electrical fire, do not use water to put it out; use a $CO_2$ fire extinguisher. If a $CO_2$ fire extinguisher is not available, you may use a dry chemical extinguisher.

*First Aid for Electrical Shock*

Basically an electrical shock is caused when a victim comes into direct contact with electrical current. The effects of electrical shock vary from minor skin tingling to complete muscle contraction and unconsciousness. Severe burns are also likely with high voltages. A shock sensation is usually present with as little as 1 mA (one-thousandth of an ampere). Currents above 5 mA can be very dangerous. A current of 12 mA, for example, if contacted by the hand, will cause the muscles to contract and will usually freeze the victim's hand to the wire or conductor. Depending on the person's physical condition, this situation could cause death. A current of 100 mA is usually fatal.

Study the following procedures for handling emergency electrical shock situations.

1. If a victim is frozen to an electrical connection and cannot free himself, remove him at once. If the power switch is handy, turn off the power. If no switch is available, use an axe with a wooden handle to sever the wires. If these options are not possible, use a belt, a dry stick, a coat, a blanket, or any nonconductor of electricity to remove the victim from the contact. Do not, however, put yourself in danger.
2. After an electric shock, it is important to have the victim lie down and remain quiet for a few minutes. If the person is unconscious, determine quickly if he or she is breathing. Loosen clothing around the neck and waist to help the victim breathe easily.
3. Call 911 to summon emergency medical assistance.

4. If the victim is breathing, treat him for shock. Have the person lie down and remain quiet. Cover him with a blanket or jacket to help retain body heat, and elevate the feet slightly (12 inches).
5. If the victim is not breathing, administer CPR immediately. Do not quit until EMS technicians arrive.

### Evaluation

Instructor evaluation of your performance will be based on participation in the activity and completion of the Safety Test.

## SAFETY TEST

Mark each of the following statements either T (true) or F (false).

___ 1. In the case of severe electrical shock, CPR is used to prevent suffocation.

___ 2. CPR should be continued until the person begins to breathe on his/her own or EMS technicians arrive.

___ 3. When attempting to remove a victim from contact with an electrical current, it is important not to place yourself in danger.

___ 4. Carbon dioxide is a good agent for putting out an electrical fire.

___ 5. An electrical current of 5 mA can be considered strong enough to pose at least some danger from electrical shock.

___ 6. An electrical current of 100 mA is, however, not dangerous.

___ 7. Voltages below 50 V are considered high voltages.

___ 8. All voltages should be considered potentially hazardous and should be treated with respect.

___ 9. If an electrical appliance or piece of electrical equipment begins to smoke, the first thing to do is to call the fire department.

___10. Neatness is not a factor to consider to ensure safe working conditions.

___11. Reading equipment schematics has no bearing on personal safety.

___12. Interlocks are designed to break the electrical circuit of some equipment when the service panel is removed.

___13. If necessary, it is proper to use a screwdriver as a chisel.

___14. It is important to think through each procedure before attempting to perform any type of electrical work.

___15. Eighty-five percent of all electrical accidents are the direct result of carelessness and general lack of caution.

ELECTRICITY/ELECTRONICS SYSTEMS
INSTRUCTOR'S RESOURCE SHEET 3
(2-3 DAYS)

# WIRING A LIGHT FIXTURE AND A RECEPTACLE

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**Essential Elements:** Common: 2, 6, 9
Specific: 1, 7
**TAAS Objectives:** Language Arts: RC 1-6

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## Activity Summary

This activity is designed to introduce students to typical NEC requirements through a practical lab project in which they will follow a wiring schematic to construct a duplex receptacle circuit including a light fixture.

## Teaching Tips

1. Read through the entire activity, and become familiar with the step-by-step details.
2. Review safety procedures for handling electrical currents and hand tools as necessary.
3. Assemble several wall sections that students can use to install their wiring and receptacles.

## Instructional Strategy

- Use the activity as either a small group or individual project.
- Lecture to present the topic to students.
- Use the demonstration method to help present the topic to students.

## Equipment/Supplies

1. Framing materials to assemble several wall sections
2. 2"x 3" electrical boxes
3. Nonmetallic sheathed cable
4. Duplex receptacles
5. Octagon boxes
6. 2-way switches
7. Light fixture and bulb
8. Wire nuts

## Evaluation Key

Instructor evaluation of student performance should be based on participation in and completion of the project.

# WIRING A LIGHT FIXTURE AND A RECEPTACLE

*Learn to install a basic household wiring system.*

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### Objectives

- To describe the general purpose of the National Electrical Code requirements
- To describe the differences between parallel and series circuits
- To install a basic household wiring system

### Vocabulary/Concepts Reinforced

- Current—the movement of electrons through an electrical circuit.
- Amperes (amps)—the amount of current flowing through an electrical circuit.
- Voltage—the amount of force that causes an electrical current to flow through a circuit. The greater the voltage applied to a circuit, the greater the amperage.
- Resistance—in an electrical circuit, there will always be some resistance to the flow of electrical current. If a circuit is made up of only wires, there would be very little resistance. If, however, we add resistance to a circuit by adding an electrical appliance, such as a toaster, the same amount of voltage will cause less current to flow.
- Watts—the common measure of the amount of voltage used to make a current flow is measured in watts. The electrical meter on the side of your house measures the number of watts used and the number of hours for which they were used.
- Circuit—a circuit is generally thought of as a system of electrical components that allow electrical current to flow from a power source, through an electrical device, and back to the power source.
- Series circuit—in a series circuit, all the components are wired in-line with each other so that the electrical current must flow through each device in order to return to the source.
- Parallel circuit—in a parallel circuit, the components are wired in such a way that the current can take one or more paths to return to the power source. Most household wiring is done in parallel circuits.
- National Electrical Code—the National Fire Protection Association publishes the NEC to establish safe standards for safe electrical systems. These standards or codes cover such things as kinds and sizes of wires, locations of outlets and fixtures, use of breakers and fuses, grounding, switches, etc.

### Equipment/Supplies

- Framed wall section
- Two 2" x 3" electrical boxes
- Nonmetallic sheathed cable
- One duplex receptacle
- One octagon box
- One 2-way switch
- One light fixture with bulb
- Wire nuts

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### Introduction

In order to understand how electrical systems work in typical buildings, it is important to develop an understanding of a few basic principles of electricity. Electricity is a form of energy which is made up of tiny particles called electrons. These electrons are made to flow through a wire, creating a form of electrical energy. This flow of energy is called the electrical *current*, and it is measured in *amperes* (or *amps*).

In order to create this flow of electrical energy, an electrical generator is needed to force or push the current through the circuit. The amount of force applied to the current is known as *voltage*. The greater the voltage applied to a circuit, the greater the number of amps. A good way to visualize how this works is to compare the process to how a fire truck pumps water through its pump and fire hose system. With little or no pressure (voltage) applied to the pump, very little water (current) passes through the hose. As the pressure of the pump increases, so does the volume of water. In an electrical circuit, as the voltage is increased, the amount of amperage also increases.

Another factor that affects the flow of electrical current is *resistance*. Resistance is any force that works against the flow of electrical current. In an electrical circuit, there is always some resistance. The wires in a circuit present a small amount of resistance, while light bulbs, fans, heaters, etc., add greater resistance. The effect of resistance can also be visualized in our example of the fire hose. If we place a nozzle on the end of the hose and close that nozzle down, we effectively cut down the flow of water. The pressure from the pump may be high, but the resistance caused by closing down the nozzle effectively slows down the flow of water. In an electrical circuit, resistance from an appliance such as a heater is high and will cause less current to flow.

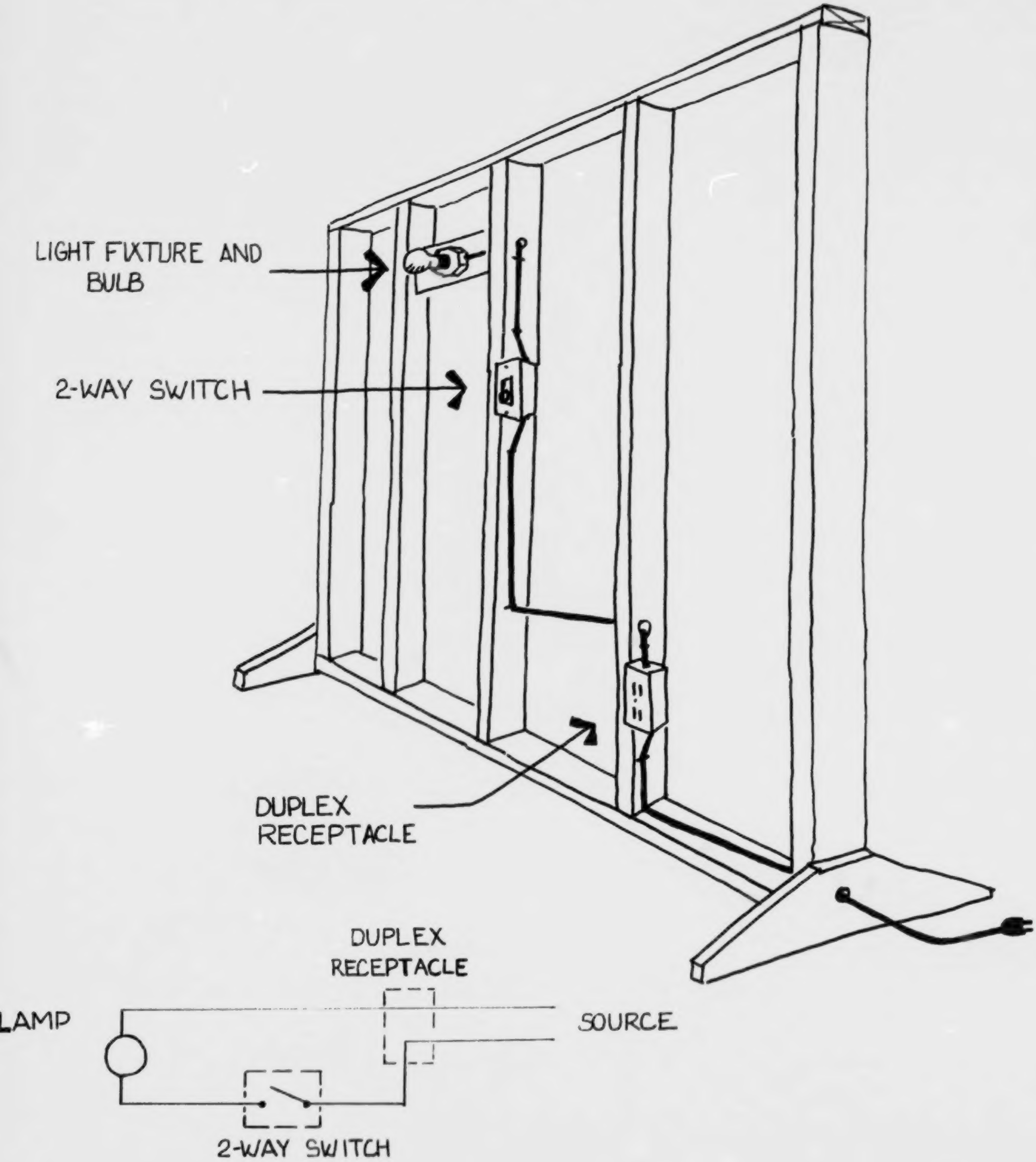
### Procedure

1. Study the schematic diagram provided.
2. Measure and cut the appropriate amount of cable. You will need about 6 inches of additional cable inside each box for each piece of cable.
3. Mount the electrical boxes as shown in the diagram.
4. Strip off about 5 inches of protective sheathing from each end of the wires, and pull them through the knock-out holes in the boxes.
5. Strip about 5/8 inch from the end of each wire, and connect as shown in the diagram. When connecting one wire to another, use a wire nut to secure them. When connecting a wire to a device, wrap the exposed wire around the terminal screw in a clockwise direction.
6. Secure each device into the necessary box.
7. Have your instructor inspect your circuit before turning on any power.
8. With your instructor's approval, turn on the power and check your circuit.
9. In a discussion of the activity, discuss how parallel circuits are used in typical household wiring.
10. Discuss with your class what happens to the flow of electrical current when additional fixtures are added to the circuit.

### Evaluation

Evaluation of student performance on this activity will be based on participation in and completion of the project.

# WIRING A LIGHT FIXTURE AND A RECEPTACLE


LIGHT FIXTURE AND BULB
2-WAY SWITCH
DUPLEX RECEPTACLE
DUPLEX RECEPTACLE
LAMP
SOURCE
2-WAY SWITCH

ELECTRICITY/ELECTRONICS SYSTEMS
INSTRUCTOR'S RESOURCE SHEET 4
(2 DAYS)

# WIRING A FIXTURE AND TWO 3-WAY SWITCHES

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**Essential Elements:** Common: 2, 6, 9
Specific:1, 7
**TAAS Objectives:** Langauge Arts: RC 1-6

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## Activity Summary

This activity is designed to follow Activity 3 in which students were introduced to basic household wiring and NEC requirements. In this activity, students will use the same wall frame sections to install a standard light fixture and two 3-way switches.

## Teaching Tips

1. Read through the entire activity, and become familiar with the step-by-step details.
2. Review safety procedures for handling electrical currents and hand tools as necessary.
3. Assemble several wall sections that students can use to install their wiring and devices.

## Instructional Strategy

- Use this activity as either a small group or individual project.
- Lecture to present the topic to students.
- Use the demonstration method to help present the topic to students.

## Equipment/Supplies

1. 2" x 3" electrical boxes
2. 3-way switches
3. Octagonal boxes
4. Nonmetallic sheathed cable
5. Light fixtures and light bulbs
6. Wire nuts
7. Framed wall sections as needed

## Evaluation Key

Instruction evaluation of student performance should be based on participation in and completion of the project.

# WIRING A FIXTURE AND TWO 3-WAY SWITCHES

*Install a standard light fixture and two 3-way switches.*

---

## Objectives

- To describe the general purpose of the National Electrical Code requirements
- To describe the differences between parallel and series circuits
- To install a basic household wiring system

## Vocabulary/Concepts Reinforced

- Current—the movement of electrons through an electrical circuit.
- Amperes (amps)—the amount of current flowing through an electrical circuit.
- Voltage—the amount of force that causes an electrical current to flow through a circuit. The greater the voltage applied to a circuit, the greater the amperage.
- Resistance—in an electrical circuit there will always be some resistance to the flow of electrical current. if a circuit is made up of only wires there would be very little resistance. If, however, we add resistance to a circuit by adding an electrical appliance, such as a toaster, the same amount of voltage will cause less current to flow.
- Watts—the common measure of the amount of voltage used to make a current flow is measured in watts. The electrical meter on the side of your house measures the number of watts used and the number oh hours for which they were used.
- Circuit—a circuit is generally thought of as a system of electrical components that allow electrical current to flow from a power source, through an electrical device, and back to the power source.
- Series circuit—in a series circuit, all the components are wired in-line with each other so that the electrical current must flow through each device in order to return to the source.
- Parallel circuit—in a parallel circuit, the components are wired in such a way that the current can take one or more paths and return to the power source. Most household wiring is done in parallel circuits.
- National Electrical Code—the National Fire Protection Association publishes the NEC to establish safe standards for electrical systems. These standards or codes cover such things as kinds and sizes or wires, locations of outlets and fixtures, use of breakers and fuses, grounding, switches, etc.

## Equipment/Supplies

- 2" x 3" electrical boxes
- Two 3-way switches
- Octagonal boxes
- Nonmetallic sheathed cable
- One light fixture and bulb
- Wire nuts

---

## Introduction

This activity follows the activity in which you completed a basic household wiring project using a parallel circuit to wire a light fixture and a receptacle. In this activity, you will install a series circuit using two 3-way switches to control a single light fixture into the simulated wall sections.

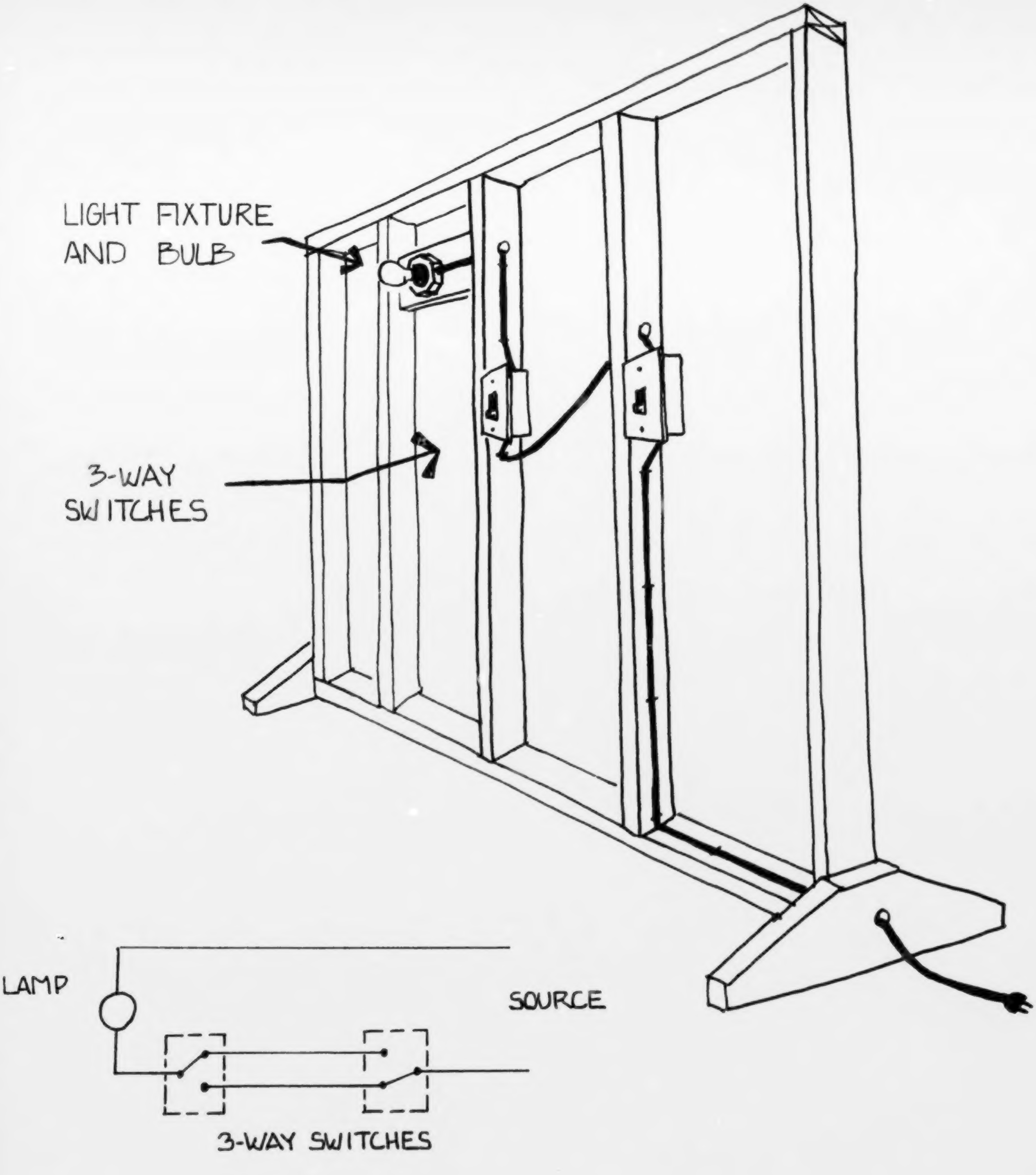
**Procedure**

1. Study the schematic diagram.
2. Measure and cut the appropriate amount of cable. You will need about 6 inches of additional cable inside each box for each piece of cable.
3. Mount the electrical boxes as shown in the diagram.
4. Strip off about 5 inches of protective sheathing from each end of the wires, and pull them through the knock-out holes in the boxes.
5. Strip about 5/8 inch from the end of each wire, and connect as shown in the diagram. When connecting one wire to another, use a wire nut to secure them. When connecting a wire to a device, wrap the exposed wire around the terminal screw in a clockwise direction.
6. Secure each device into the necessary box.
7. Have your instructor inspect your circuit before turning on any power.
8. With your instructor's approval, turn on the power and check your circuit.
9. In a discussion of the activity, discuss how series circuit connections are used in typical household wiring.
10. Discuss with your class the need for application of NEC electrical codes and the importance of municipal building inspectors.

**Evaluation**

Evaluation of student performance on this activity will be based on participation in and completion of the activity.

# WIRING A LIGHT FIXTURE CONTROLLED BY TWO 3-WAY SWITCHES


LIGHT FIXTURE AND BULB
3-WAY SWITCHES
LAMP
SOURCE
3-WAY SWITCHES

# A SOFT DRINK CIRCUIT

---

**Essential Elements:** Common: 1-6
Specific: 1-3
**TAAS Objectives:** Mathematics: C 1, 4, 5; O 1, 2
Language Arts: RC 1-6; WC 5-7

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## Activity Summary

The purpose of this activity is to produce electricity from chemical action and at the same time introduce the parts of a circuit and the function of each. Further enlargement of this activity might be to introduce series, parallel, and series-aiding circuits, as well as basic DC concepts.

## Teaching Tips

1. Review activity, asking for questions through each stage of activity.
2. Explain relationship between electricity and matter.
3. Use several combinations of electrodes and test voltage relationships.
4. To light the LED, it might take several cells of soft drinks wired in series.

## Instructional Strategy

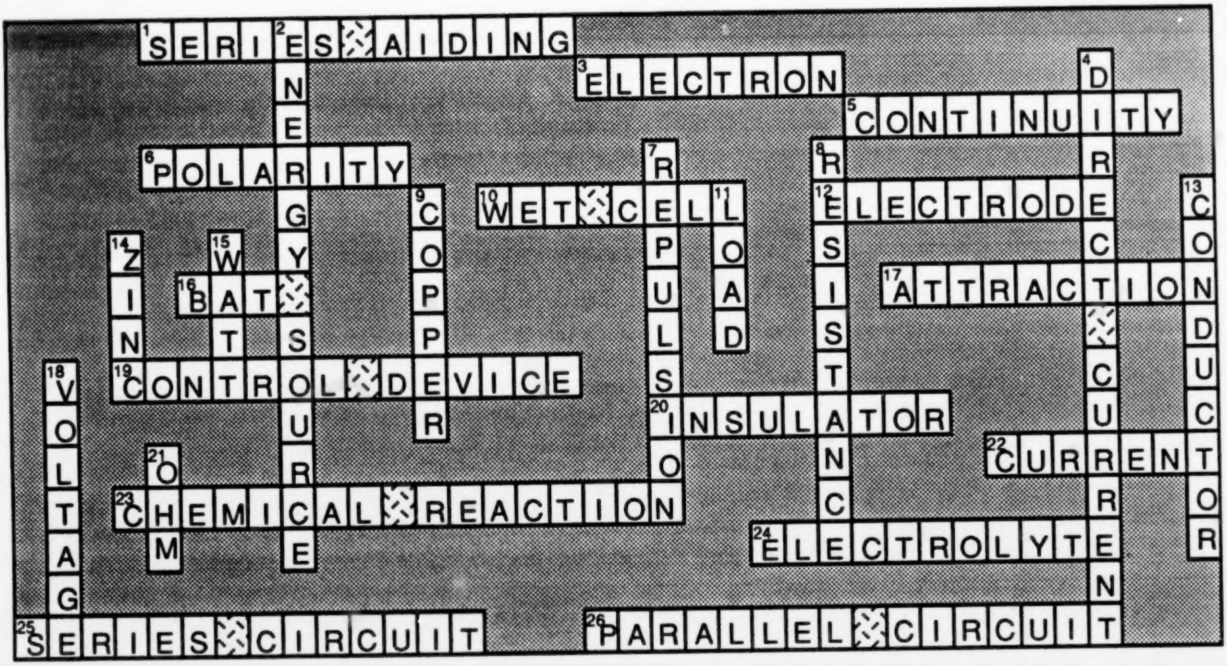
- Set introduction or focus by presenting the soft drink as packaged, and then ask students if it would be possible to build a functional circuit from the materials on the desk.
- When curiosity level reaches maximum, demonstrate the activity explaining chemical reaction, parts of a circuit, and circuit functions.
- Have students write a hypothesis statement before the activity, stating which soft drink they predict will serve as the best electrolyte.
- Allow students time to try combinations of soft drink cells, circuit materials, and lab tools to light an LED.

## Equipment/Supplies

1. One beaker
2. One or more cans of soft drinks
3. Sheet metal (galvanized), cut into 1/4" wide strips; length depends on depth of beaker
4. Nickel coin
5. One foot of copper wire
6. One galvanometer
7. Jumper wires with clips
8. One or more LEDs (light-emitting diodes)
9. One pair of leather gloves
10. Tin snips
11. Safety glasses
12. One switch per circuit

## Evaluation Key

The teacher may use any evaluation method depending on the availability of lab materials and the discretion of the teacher.


1 SERIES AIDING
2 ENERGY SOURCE
3 ELECTRON
4 DIRECT CURRENT
5 CONTINUITY
6 POLARITY
7 REPULSION
8 RESISTANCE
9 COPPER
10 WET CELL
11 LOAD
12 ELECTRODE
13 CONDUCTOR
14 ZINC
15 WATT
16 BAT
17 ATTRACTION
18 VOLTAGE
19 CONTROL DEVICE
20 INSULATOR
21 OHM
22 CURRENT
23 CHEMICAL REACTION
24 ELECTROLYTE
25 SERIES CIRCUIT
26 PARALLEL CIRCUIT

ELECTRICITY/ELECTRONICS SYSTEMS
STUDENT ACTIVITY 5

# A SOFT DRINK CIRCUIT

*Understand how a soft drink might be used to produce electrical energy.*

---

## Objectives

- To describe the conversion of energy
- To identify four parts of a circuit
- To explain basic DC theory
- To identify the terms related to a basic DC circuit

## Vocabulary/Concepts Reinforced

- Series aiding—the adding of cells or components
- Electron—negative charged particle
- Continuity—path that allows for current flow
- Polarity—either positive or negative
- Wet cell—liquid cell
- Electrode—a plate of a cell
- Bat—two or more cells connected to add
- Attraction—pulling together
- Control device—switch
- Insulator—plastic coating on a conductor
- Current—flow of electrons
- Chemical reaction—relationships between atoms
- Electrolyte—liquid acid
- Series circuit—circuit; one behind the other
- Parallel circuit—circuit; components aligned
- Energy source—voltage, e.m.f.
- Copper—cu
- Repulsion—pushing apart
- Load—light bulb, meter, motor
- Resistance—opposition to current flow
- Direct current—voltage produced by a battery
- Conductor—copper wire
- Voltage—electrical pressure
- Zinc—galvanized electrode
- Ohm—resistance measurement
- Watt—measurement of power

## Equipment/Supplies

- One beaker
- One or more cans of soft drinks
- Sheet metal (galvanized), cut into 1/4" wide strips; length depends on depth of beaker
- A nickel coin
- One foot of copper wire
- One galvanometer
- Jumper wires with clips
- One or more LEDs (light-emitting diodes)
- One pair of leather gloves
- Tin snips
- Safety glasses
- One switch per circuit

## Introduction

Everything is held together electrically. Because of this fact, we must appreciate the importance of electricity. Even the liquids you drink and the food you eat contain tiny particles called **electrons** that travel about a nucleus. These tiny particles are all negatively charged and are either attracted or repelled by other particles. That is the principle of electron flow.

Positive and negative charges attract which allow multiple uses. These electrons travel, and when they do work we call it **power.** Electric circuits are what allow electrons to work for us. A complete circuit is made up of—

1. **voltage**—which is electrical pressure;
2. **conductor**—a path for current flow;
3. **current**—electrons moving through the conductor;
4. a control device or **switch**; and
5. a **load** that performs work.

A light at home is a load, and it is rated in **watts** (how much work it can do). A circuit, then, contains an **energy source,** a path for electrons, a load, and some control device (switch) to turn the electrons on or off.

In this activity, you will build a circuit using a soft drink as the **electrolyte** for each cell. Each cell includes a set of **electrodes**, one of **zinc** and the other of **copper**. The conductor for the circuit is also copper wire, which is insulated. The load for the circuit is the galvanometer, and the switch is the control device.

When a circuit is built, electrons will flow through the circuit and cause the needle on the galvanometer to move. This circuit, when built, is called a **series circuit** because each component is one behind the other or in series. If we put one cell behind another cell and connect our polarity correctly, we can cause each cell's voltage to add, which is called **series aiding.** If we connect several loads to one cell with the loads parallel to each other, we call it (you guessed it) a **parallel circuit.**

Cells come in two types: **wet or dry**. A flashlight usually requires dry cells to operate. The circuit you will build, or watch being built, is a wet cell. When two or more cells are placed in series, they add and then become a battery. It takes several cells to make a battery.

When a cell or a battery is connected to a load and it works for us, it is said to possess **continuity**. Continuity is just a fancy word taken from continue. It just means that there is a path for current to flow. If this path is broken, it is said to be *open* because of high resistance to electron flow, which may not allow current to flow. The resistance of the open is measured in **ohms**. The higher the resistance, the higher the ohms rating.

Electricity that you produce with your soft drink circuit is called DC or direct current. Other devices can produce DC or AC (alternating current).

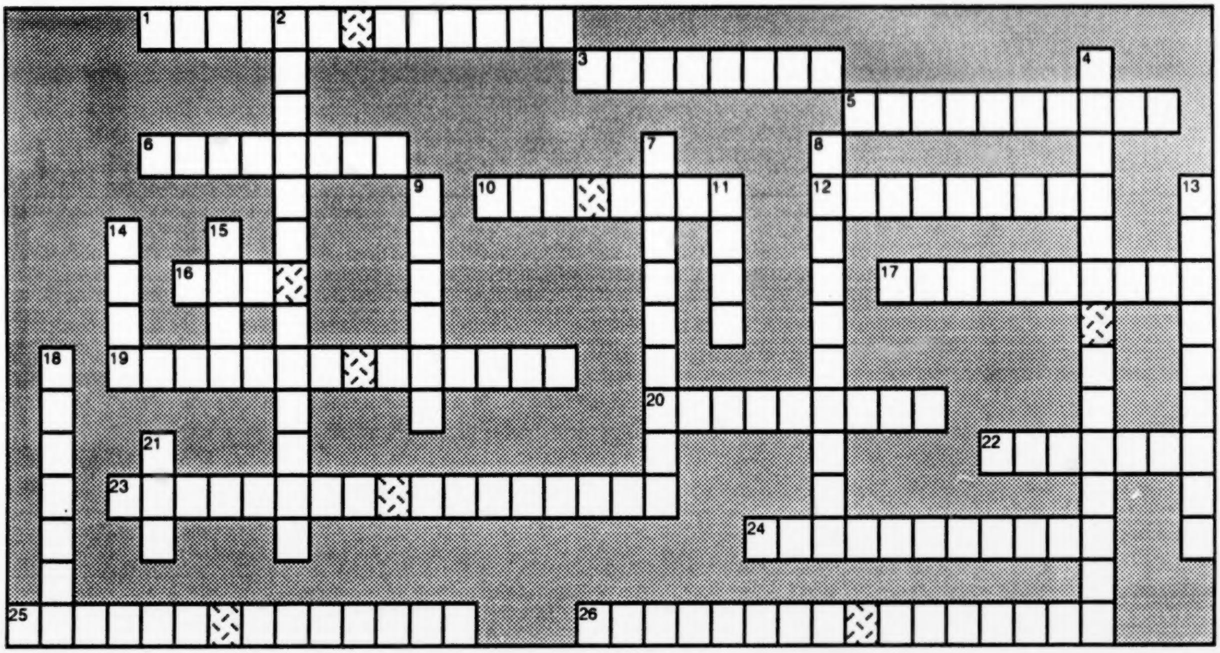
## Procedure

1. Coolect all necessary materials and supplies.
2. Cut and clean/sand the galvanized metal and coin (electrodes).

3. Connect the electrodes, jumper wires with clips, switch, and galvanometer into a complete circuit.
4. Pour soft drink (electrolyte) into container, and place electrodes into the electrolyte.
5. Measure reading on the galvanometer, and record your reading.
6. Repeat steps 4 and 5 comparing other soft drinks.

**Evaluation**

Submit your written findings to your instructor.



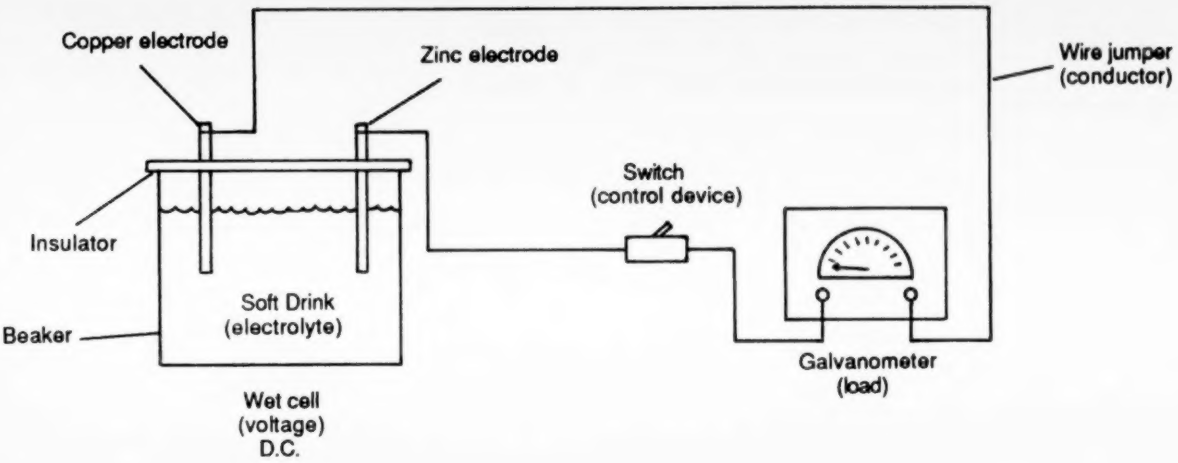
ACROSS = 15 clues

1 The adding of cells or components
3 Negative charged particle
5 Path that allows for current flow
6 Either positive or negative
10 Liquid cell
12 A plate of a cell
16 Two or more cells connected to add
17 Pulling together
19 Switch
20 Plastic coating on a conductor
22 Flow of electrons
23 Relationships between atoms
24 Liquid acid
25 Circuit; one behind the other
26 Circuit; components aligned

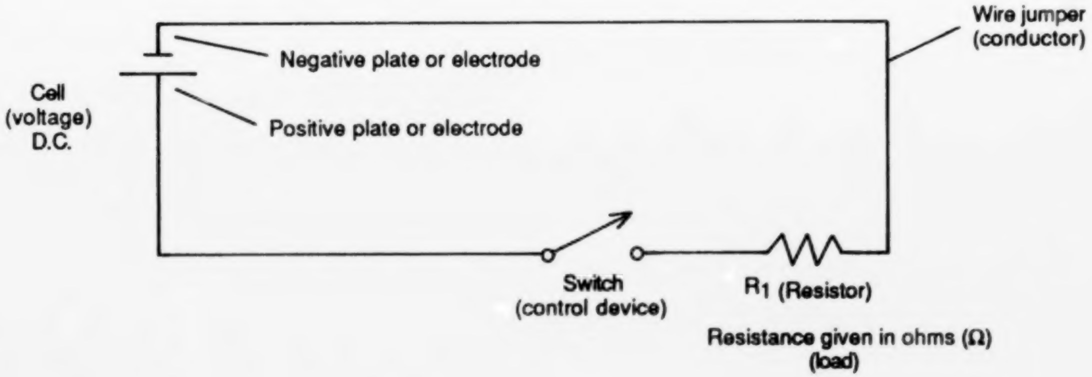
DOWN = 11 clues

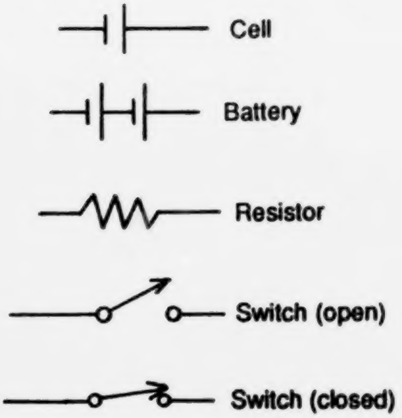
2 Voltage, e.m.f.
4 Voltage produced by a battery
7 Pushing apart
8 Opposition to current flow
9 Cu
11 Light bulb, meter, motor
13 Copper wire
14 Galvanized electrode
15 Measurement of power
18 Electrical pressure
21 Resistance measurement

## Soft Drink Circuit


Copper electrode
Zinc electrode
Wire jumper
(conductor)
Switch
(control device)
Insulator
Soft Drink
(electrolyte)
Beaker
Galvanometer
(load)
Wet cell
(voltage)
D.C.

## Schematic of Above Circuit


Wire jumper
(conductor)
Negative plate or electrode
Cell
(voltage)
D.C.
Positive plate or electrode
Switch
(control device)
R1 (Resistor)
Resistance given in ohms (Ω)
(load)


Cell
Battery
Resistor
Switch (open)
Switch (closed)

ELECTRICITY/ELECTRONICS SYSTEMS
INSTRUCTOR'S RESOURCE SHEET 6
(1 DAY)

# SEMICONDUCTOR JUNCTION DIODE CHARACTERISTICS

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| | |
|---|---|
| **Essential Elements:** | Common: 6A, 6B, 8C, 9A, 9B<br>Specific: 1, 3, 10 |
| **TAAS Objectives:** | Mathematics: C 1, 4<br>Language Arts: RC 4, 5; WC 1 |

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## Activity Summary

This activity is designed to give students the opportunity to investigate the characteristics of semiconductor junction diodes using the ohmmeter function of a multimeter. Students will also investigate the operation of a diode in a direct current circuit.

## Teaching Tips

1. Read through the activity before beginning the activity.
2. Reproduce activity sheets for each student, or lab group, before the activity.
3. Organize all equipment and supplies before the activity.

## Instructional Strategy

- Explain semiconductor characteristics.
- Explain the construction of a junction diode.
- Introduce the schematic symbol for a junction diode.
- Explain and demonstrate the forward and reverse bias testing procedure for a diode using the ohmmeter function of a multimeter.
- Explain and demonstrate the operation of a diode in a direct current circuit.

## Equipment/Supplies

1. 6-volt lantern battery
2. 1N4001 diode
3. No. 47 incandescent lamp with lamp holder
4. Single-pole switch
5. Proto-board with connecting wires
6. Analog, or digital, multimeter

## Evaluation Key

1. Instructor evaluation of student's ability to follow the procedures of the activity sheet.
2. Instructor evaluation of student's ability to obtain desired information from the ohmmeter function of the multimeter.
3. Instructor evaluation of student's ability to follow safety guidelines established for test equipment and voltage source.

# SEMICONDUCTOR JUNCTION DIODE CHARACTERISTICS

*Experiment with the characteristics of a semiconductor junction diode.*

---

## Objectives

- To identify semiconductor junction diodes
- To identify the anode and cathode terminals of a diode
- To operate the multimeter to given standards when testing the forward and reverse bias characteristics of a diode
- To identify the operational characteristics of a diode in a direct current circuit

## Vocabulary/Concepts Reinforced

- Semiconductor
- P-type semiconductor
- N-type semiconductor
- Doping
- Junction diode
- P-N junction
- Depletion region
- Potential barrier
- Anode
- Cathode
- Forward bias
- Reverse bias
- Avalanche voltage
- Breakdown voltage
- Peak inverse voltage

## Equipment/Supplies

- 6-volt lantern battery
- 1N4001 diode
- No. 47 incandescent lamp with lamp holder
- Single-pole switch
- Proto-board with connecting wires
- Analog, or digital, multimeter

---

## Introduction

Diodes are one of the most basic and versatile of all semiconductor devices. A diode allows current to flow through it in only one direction. *Semiconductors* are materials with electrical characteristics between a conductor and an insulator. Silicon is the most widely used semiconductor material.

To increase the conductivity of silicon, impure materials are added to molten silicon before it is formed into crystals. The process of adding impurities to a semiconductor is called *doping*. Silicon atoms contain four valence, or outer shell, electrons. When silicon is doped with arsenic, or another atom with five valence electrons, an extra electron is placed into the lattice structure formed by the silicon atoms. The electron that does not bond with the other electrons of the atoms can be easily moved. The effect of this free electron causes the doped silicon to have the same characteristics as a negatively charged material. Silicon that is doped with a material with five valence electrons is called an *N-type semiconductor*. An N-type semiconductor will donate the free electron from the arsenic atom.

To produce a *P-type semiconductor*, silicon is doped with a material with three valence electrons. Boron is a common P-type semiconductor doping material. When boron is added to silicon, the three valence electrons of boron bond with the four valence electrons of each of the surrounding silicon atoms. This bonding leaves one valence electron of a nearby silicon atom without an electron-pair bond to complete the lattice structure. This space, or hole, causes the doped silicon to have the same characteristics as a positively charged material. A P-type semiconductor will accept electrons to fill the holes produced by the boron atoms.

A *junction diode* is produced by chemically combining a P-type semiconductor with an N-type semiconductor on a single crystal of silicon. The area where the P-type semiconductor meets the N-type semiconductor is called the *P-N junction*. At the P-N junction, free electrons from the N-type material move across the junction to fill the holes of the P-type material near the junction. This movement of free electrons to fill the holes at the junction produces a *depletion region*. A small potential, or voltage, is produced at the depletion region to stop the diffusion of a large number of electrons from the N-type region from filling the holes of the P-type region. This voltage produced across the depletion region is called the *potential barrier*.

Diodes are enclosed in a protective case, and the P-type and N-type regions are identified on the case. The P-type region of a diode is called the *anode*. The N-type region of a diode is called the *cathode*. Care must be taken when placing a diode in a circuit to assure that the anode and cathode are attached in the proper direction.

The potential barrier of a diode must be overcome in order for the diode to conduct. The conducting state of a diode is called *forward bias*. Forward bias occurs if a diode is connected to a battery with the negative terminal of the battery connected to the cathode of the diode and the positive terminal of the battery connected to the anode of the diode. The electrons from the negative terminal of the battery will force the free electrons of the cathode of the diode through the depletion region and the anode toward the positive terminal of the battery.

When the potential barrier is increased, a diode acts as an insulator. The insulating state of a diode is called *reverse bias*. Reverse bias occurs if a diode is connected to a battery with the negative terminal of the battery connected to the anode of the diode and the positive terminal of the battery connected to the cathode of the diode. The electrons from the negative terminal of the battery will attract the holes of the anode of the diode, while the positive terminal of the battery will attract the electrons of the cathode of the diode. This will increase the size of the depletion region, which acts as an insulator. The voltage in a circuit can be increased to a level that will force electrons through the depletion region of a diode in reverse bias. This voltage is called the *breakdown, or avalanche, voltage*. Diodes are rated for their *peak inverse voltage*, which is the maximum reverse bias voltage of a diode. It is the forward and reverse bias states of a diode that allows current flow through in only one direction.

The ohmmeter function of a multimeter can be used to test a diode for proper operation. An ohmmeter uses a direct current power source to provide a reference voltage to measure resistance. The resistance produced by the diode should be low; then the negative terminal of an ohmmeter is connected to the cathode of a diode, and the positive terminal of the ohmmeter is connected to the anode of the diode. This connection of the ohmmeter places the diode in forward bias. The resistance produced by the diode should be high when the negative terminal of an ohmmeter is connected to the anode of a diode and the positive terminal of the ohmmeter is connected to the cathode of the diode. This connecting of the ohmmeter places the diode in reverse bias.

This activity will demonstrate the forward and reverse bias characteristics of a semiconductor junction diode. The ohmmeter function of a multimeter will be used to test the diode. The diode will be placed in a direct current circuit to investigate the current flow characteristics of a diode.

**Procedure**

1. Locate the diode and the multimeter at the lab station.
2. Set the multimeter to the highest range of the ohmmeter function.
3. Place the positive probe of the ohmmeter on the anode of the diode.
4. Place the negative probe of the ohmmeter on the cathode of the diode.
5. Record the resistance value produced by the diode.

6. Place the positive probe of the ohmmeter on the cathode of the diode.
7. Place the negative probe of the ohmmeter on the anode of the diode.
8. Record the resistance value produced by the diode.

9. Compare the resistance values produced by the diode in **Step 5** with resistance value of the diode produced in **Step 8**. Explain the reason for the difference in the resistance values.

10. Locate the proto-board with connecting wires, 6V battery, switch, lamp, and lamp holder.
11. Construct the circuit in **Figure 1** on the proto-board. Connect the battery and diode in the direction shown in the schematic diagram.
12. Turn the circuit switch to the "on" position.
13. Does the lamp produce light? Why does this result occur?

14. Turn the multimeter to the proper DC voltmeter range to measure the circuit voltage values.
15. Measure and record the voltage produced by the 6V battery at **Test Points A** and **D**. (Observe polarity.)

$V_S$ = ____________ V

16. Place the positive probe of the voltmeter at **Test Point A** and the negative probe at **Test Point B** to measure the voltage drop across the diode.
17. Measure and record the voltage drop across the diode.

$V_{D1}$ = ____________ V

18. Place the positive probe of the voltmeter at **Test Point B** and the negative probe at **Test Point C** to measure the voltage drop across the lamp.
19. Measure and record the voltage drop across the lamp.

$V_{LAMP1}$ = ____________ V

20. How does the voltage drop across D1 measured in **Step 17** compare to the voltage drop across LAMP1 measured in **Step 19**? Explain the reason for this result.

21. Turn the circuit switch to the "off" position.
22. Reverse the diode in the circuit.
23. Turn the circuit switch to the "on" position.
24. Does the lamp produce light? Why does this result occur?

25. Place the positive probe of the voltmeter at **Test Point A** and the negative probe at **Test Point B.**
26. Measure and record the voltage drop across the diode.

$V_{D1}$ = ____________ V

27. Place the positive probe of the voltmeter at **Test Point B** and the negative probe at **Test Point C**.
28. Measure and record the voltage drop across the lamp.

$V_{LAMP1}$ = ____________ V

29. How does the voltage drop across D1 measured in **Step 26** compare to the voltage drop across LAMP1 measured in **Step 28**? Explain the reason for this result.

30. Turn the circuit switch to the "off" position, and disconnect the circuit. Turn off the multimeter.

**Evaluation**
See your instructor for evaluation procedure.

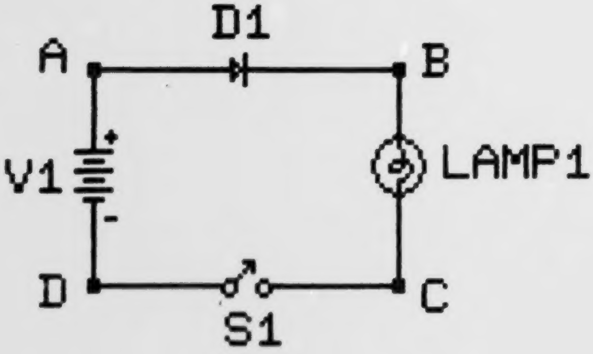

Figure 1

# HALF-WAVE RECTIFIER CHARACTERISTICS

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**Essential Elements:** Common: 6A, 6B, 8C, 9A, 9B
Specific: 1, 3, 10
**TAAS Objectives:** Mathematics: C 1, 4
Language Arts: RC 4, 5; WC 1

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## Activity Summary

This activity is designed to give students an opportunity to investigate the characteristics of a half-wave rectifier circuit. A semiconductor junction diode will be used as the rectifying device. This activity will use a center-tapped, step-down transformer as the power source. An oscilloscope and a multimeter will be used to test the characteristics of the half-wave rectifier circuit.

## Teaching Tips

1. Read through the activity before beginning it.
2. Reproduce activity sheets for each student, or lab group, before the activity.
3. Organize all equipment and supplies before the activity.

## Instructional Strategy

- Explain the construction of a semiconductor junction diode.
- Explain and demonstrate the operation of a diode in an alternating current circuit.
- Explain the construction and operation of a center-tapped, step-down transformer.
- Explain and demonstrate the construction of a half-wave rectifier circuit using a schematic diagram.
- Explain the testing procedure for a half-wave rectifier using a multimeter and an oscilloscope.

## Equipment/Supplies

1. 12.6V center-tapped, step-down transformer
2. 1N4001 diode
3. No. 47 incandescent lamp with lamp holder
4. Single-pole switch
5. Proto-board with connecting wires
6. Analog, or digital, multimeter
7. B&K 1405 oscilloscope

## Evaluation Key

1. Instructor evaluation of student's ability to follow the procedures of the activity sheet.
2. Instructor evaluation of student's ability to construct a half-wave rectifier circuit on a proto-board using a schematic diagram.
3. Instructor evaluation of student's ability to obtain desired circuit information from the voltmeter function of the multimeter.
4. Instructor evaluation of student's ability to obtain desired circuit information from the voltmeter function of an oscilloscope.
5. Instructor evaluation of student's ability to follow safety guidelines established for test equipment and voltage source.

# HALF-WAVE RECTIFIER CHARACTERISTICS

*Experiment with the characteristics of a half-wave rectifier circuit.*

## Objectives

- To identify the components of the half-wave rectifier circuit
- To construct the half-wave rectifier circuit
- To operate the voltmeter function of a multimeter to given standards when testing half-wave rectifier circuit characteristics
- To operate the oscilloscope to given standards when testing half-wave rectifier circuit characteristics
- To identify the operational characteristics of a diode in an alternating current circuit

## Vocabulary/Concepts Reinforced

- Junction diode
- Rectifier
- Alternating current
- Direct current
- Anode
- Cathode
- Forward bias
- Reverse bias
- Half-wave rectifier
- Pulsating direct current
- Center-tapped, step-down transformer

## Equipment/Supplies

- 12.6V center-tapped, step-down transformer
- 1N4001 diode
- No. 47 incandescent lamp with lamp holder
- Single-pole switch
- Proto-board with connecting wires
- Analog, or digital, multimeter
- B&K 1405 oscilloscope

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## Introduction

A rectifier is an electronic circuit that converts alternating current to direct current. In alternating current, electron flow changes direction at a periodic rate. This change in direction of the current flow produces a sine wave pattern for each cycle of current flow. In direct current, electrons flow in only one direction. A semiconductor junction diode is commonly used as a rectifier device because of its ability to allow current flow through it in only one direction.

A diode will allow current flow though it when electrons flow from the cathode, or negative terminal of the diode, to the anode, or positive terminal of the diode. The conducting state of a diode is called *forward bias*. Current flow will be stopped in a circuit when electrons try to flow from the anode to the cathode of a diode. The insulating state of a diode is called *reverse bias*.

When alternating current is applied to a diode, it causes the diode to become alternately forward-biased and then reverse-biased during each cycle of current flow. A diode will allow only one half cycle of a sine wave to pass through it. An alternating current circuit containing a single diode is called a *half-wave rectifier.*

The output of a half-wave rectifier circuit is called *pulsating direct current.* The output power of a half-wave rectifier is decreased because half of the alternating current signal is eliminated. Half-wave rectifiers are usually limited to circuits with low power demands.

A center-tapped, step-down transformer will be used to provide the alternating current power in this circuit. The secondary winding of the transformer is divided, or center-tapped, in order to split the output voltage level. The center-tapped, step-down transformer is used to lower the 120V of alternating current from the receptacle to a voltage level that is appropriate for the circuit.

This activity will demonstrate the characteristics of a half-wave rectifier circuit. The voltmeter function of a multimeter will be used to test the input voltage provided by the center-tapped, step-down transformer and the output voltage produced by the half-wave rectifier circuit. The oscilloscope will also be used to compare the input voltage provided by the center-tapped, step-down transformer and the output voltage produced by the half-wave rectifier.

## Procedure

1. Locate the proto-board with connecting wires, center-tapped, step-down transformer, diode, switch, and lamp with lamp holder at the lab station.
2. Construct the circuit in **Figure 1** on the proto-board. Connect the diode in the direction shown on the schematic diagram.
3. Turn the circuit switch to the "on" position.
4. Does the lamp produce light? Why does this result occur?

5. Turn on the oscilloscope.
6. Set the SWEEP RANGE setting to the 10-100 position.
7. Set the V. ATT setting to the 1/100.
8. Set the AC/DC setting to the DC position.
9. Attach the oscilloscope probes to the transformer terminals connected to the circuit at **Test Points A** and **D**. Draw the waveform.

10. Attach the probes of the oscilloscope to the terminals of the lamp at **Test Points B** and **C**. Draw the waveform.

11. How does the waveform produced by the transformer in **Step 9** compare to the waveform observed across the lamp in **Step 10?** Why does this result occur?

12. Set the multimeter to the proper AC voltmeter range to measure the voltage output of the transformer terminals attached to the circuit.

13. Measure and record the voltage at the transformer terminals at **Test Points A** and **D.**

$V_{T1}$ = ________________V

14. Set the multimeter to the proper DC voltmeter range to measure the voltage drop across the lamp.
15. Connect the positive probe of the multimeter to **Test Point B** and the negative probe of the multimeter to **Test Point C**. Measure and record the voltage drop across the lamp.

$V_{LAMP1}$ = ________________V

16. How does the alternating current voltage produced by the transformer measured in **Step 13** compare to the direct current voltage drop across the lamp measured in **Step 15?** Why does this result occur?

17. Turn the circuit switch to the "off" position.
18. Reverse the diode in the circuit.
19. Turn the circuit switch to the "on" position.
20. Does the lamp produce light? Why does this result occur?

21. Attach the probes of the oscilloscope to the terminals of the lamp at **Test Points B** and **C**. Draw the waveform.

22. How does the waveform observed across the lamp in the first circuit in **Step 10** compare to the waveform observed across the lamp in this circuit in **Step 21?** Why does this result occur?

23. Set the multimeter to the proper DC voltmeter range to measure the voltage drop across the lamp.
24. Connect the positive probe of the multimeter to **Test Points C** and the negative probe of the multimeter to **Test Point B**. Measure and record the voltage drop across the lamp.

$V_{LAMP1}$ = ________________V

25. How does the direct current voltage drop across the lamp in the first circuit measured in **Step 15** compare to the direct current voltage drop across the lamp in this circuit measured in **Step 24?** Why does this result occur?

26. Turn off the circuit switch, unplug the transformer, disconnect the circuit, and turn off the multimeter and the oscilloscope.

**Evaluation**
See your instructor for evaluation procedure.

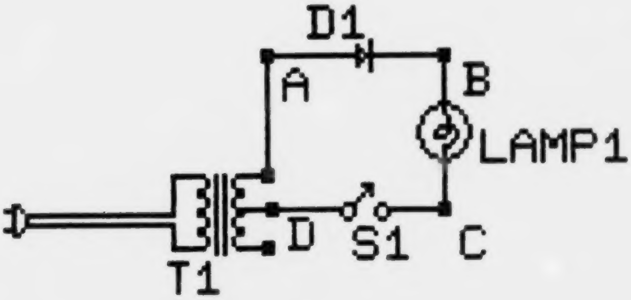

Fig. 1. Half-wave rectifier

# FULL-WAVE RECTIFIER CHARACTERISTICS

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**Essential Elements:** Common: 6A, 6B, 8C, 9A, 9B
Specific: 1, 3, 10
**TAAS Objectives:** Mathematics: C 1, 4
Language Arts: RC 4, 5; WC 1

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## Activity Summary

This activity is designed to provide students with the opportunity to investigate the characteristics of a full-wave rectifier circuit. Two semiconductor junction diodes will be used as the rectifying devices. This activity will use a center-tapped, step-down transformer as the power source. An oscilloscope and a multimeter will be used to test the characteristics of the full-wave rectifier circuit.

## Teaching Tips

1. Read through the activity before beginning it.
2. Reproduce activity sheets for each students, or lab group, before the activity.
3. Organize all equipment and supplies before the activity.

## Instructional Strategy

- Explain the construction of a semiconductor junction diode.
- Explain and demonstrate the operation of a diode in an alternating current circuit.
- Explain the construction and operation of a center-tapped, step-down transformer in a full-wave rectifier circuit.
- Explain and demonstrate the construction and operation of a full-wave rectifier circuit using a schematic diagram.
- Explain the testing procedure for a full-wave rectifier using a multimeter and an oscilloscope.

## Equipment/Supplies

1. 12.6V center-tapped, step-down transformer
2. Two 1N4001 diodes
3. No. 47 incandescent lamp with lamp holder
4. Proto-board with connecting wires
5. Analog, or digital, multimeter
6. B&K 1405 oscilloscope

## Evaluation Key

1. Instructor evaluation of student's ability to follow the procedures of the activity sheet.
2. Instructor evaluation of student's ability to recognize the components used in a full-wave rectifier circuit.
3. Instructor evaluation of student's ability to construct a full-wave rectifier circuit on a proto-board using a schematic diagram.
4. Instructor evaluation of student's ability to obtain desired full-wave rectifier circuit information from the voltmeter function of the multimeter.

5. Instructor evaluation of student's ability to obtain desired full-wave rectifier circuit information from an oscilloscope.
6. Instructor evaluation of student's ability to follow safety guidelines established for test equipment and voltage source.

# FULL-WAVE RECTIFIER CHARACTERISTICS

*Experiment with the characteristics of a full-wave rectifier circuit.*

---

## Objectives

- To identify the components of the full-wave rectifier circuit
- To construct a full-wave rectifier circuit
- To operate the voltmeter function of a multimeter to given standards when testing full-wave rectifier circuit characteristics
- To operate the oscilloscope to given standards when testing full-wave rectifier circuit characteristics
- To identify the operational characteristics of a diode in a full-wave rectifier circuit

## Vocabulary/Concepts Reinforced

- Junction diode
- Rectifier
- Half-wave rectifier
- Full-wave rectifier
- Anode
- Cathode
- Pulsating direct current
- Center-tapped, step-down transformer

## Equipment/Supplies

- 12.6V center-tapped, step-down transformer
- Two 1N4001 diodes
- No. 47 incandescent lamp with lamp holder
- Proto-board with connecting wires
- Analog, or digital, multimeter
- B&K 1405 oscilloscope

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## Introduction

A full-wave rectifier circuit doubles the pulsating direct current output of a half-wave rectifier. A full-wave rectifier can use both alternations of an alternating current sine wave to produce pulsating direct current. The full-wave rectifier circuit in this activity uses two diodes and a center-tapped, step-down transformer.

The center-tapped transformer provides a terminal, or center tap, that divides the secondary winding. When alternating current is applied to the primary winding on the transformer, the secondary winding produces an equal voltage on each side of the center tap. The construction of the transformer causes the voltages to be of equal value but of opposite polarity with respect to the center tap. For one alternation or half cycle, one outer terminal is positive while the other outer terminal is negative. During the next alternation, the polarity of the two terminal windings are reversed.

The two diodes are connected to the two outer terminals of the transformer. Connecting the diodes to the two outer terminals of the transformer allows one diode to conduct during the positive alternation and the other diode to conduct during the negative alternation. Current flow through the load travels in the same direction during both alternations. In the circuit for this activity, the anodes of both the diodes are connected to the two outer terminals of the transformer. The cathodes of the two diodes are connected together and serve as the positive direct current output terminal for the load. The center tap of the transformer serves as the negative direct current output terminal for the load.

A full-wave rectifier is a much more efficient power supply than a half-wave rectifier because of the increased power output. The use of a center-tapped transformer can be a disadvantage because of its size, weight, and cost.

This activity will demonstrate the characteristics of a full-wave rectifier circuit. The voltmeter function of a multimeter will be used to test the input voltage provided by the center-tapped, step-down transformer and the output voltage produced by the full-wave rectifier circuit. The oscilloscope will also be used to compare the input voltage provided by the center-tapped, step-down transformer and the output voltage produced by the full-wave rectifier.

## Procedure

1. Locate the proto-board with connecting wires, center-tapped, step-down transformer, two diodes, and lamp with lamp holder at the lab station.
2. Construct the circuit in **Figure 1** on the proto-board. Connect the diodes in the direction shown on the schematic diagram.
3. Plug the transformer cord into the receptacle.
4. Does the lamp produce light? Why does this result occur?

5. Turn on the oscilloscope.
6. Set the SWEEP RANGE setting to the 10-100 position.
7. Set the V.ATT setting to the 1/100 position.
8. Set the AC/DC setting to the DC position.
9. Attach the oscilloscope probes to the transformer terminals at **Test Points A** and **E.** Draw the waveform.

10. Attach the oscilloscope probes to the transformer terminals at **Test Points F** and **E.** Draw the waveform.

11. How do the waveforms produced at the center tap and at the two outer terminals of the transformer observed in **Steps 9** and **10** compare?

12. Observe the waveform produced across D2 by connecting the GROUND probe of the oscilloscope to **Test Point G** and the VERT INPUT probe of the oscilloscope to **Test Point F.** Draw the waveform.

14. How does the waveform produced across D1 observed in **Step 12** compare to the waveform produced across D2 observed in **Step 13**?

15. Observe the waveform produced across the lamp by connecting the GROUND probe of the oscilloscope to **Test Point D** and the VERT INPUT probe of the oscilloscope to **Test Point C**. Draw the waveform.

16. How does the waveform produced across D1 and D2 in **Steps 12** and **13** compare to the waveform observed across the lamp in **Step 15**? Why does this result occur?

17. Set the multimeter to the proper AC voltmeter range to measure the voltage output of the transformer at the center tap and one of the outer terminals.
18. Measure and record the voltage at the transformer terminals at **Test Points A** and **E**.

$V_{T1}$ =________________V

19. Measure and record the voltage at the transformer terminals at **Test Points F** and **E**.

$V_{T1}$ =________________V

20. How do the voltage values compare across the center tap and at each of the outer terminals of the transformer measured in **Steps 18** and **19**?

21. Set the multimeter to the proper DC voltmeter range to measure the voltage drop across the lamp.
22. Connect the positive probe of the multimeter to **Test Point C** and the negative probe of the multimeter to **Test Point D**. Measure and record the voltage drop across the lamp.

$V_{LAMP1}$ =________________V

23. How does the alternating current voltage produced by the transformer measured in **Step 18** and **19** compare to the direct current voltage drop across the lamp measured in **Step 22**? Why does this result occur?

24. Unplug the transformer, and disconnect the circuit.
25. Turn off the multimeter and the oscilloscope.

**Evaluation**

See your instructor for evaluation procedure.

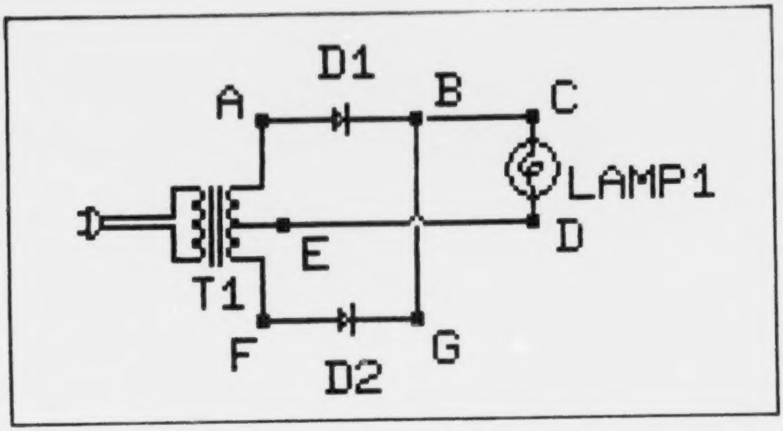
D1
A
B
C
LAMP1
D
E
T1
F
G
D2

Fig. 1. Full-wave rectifier

ELECTRICITY/ELECTRONICS SYSTEMS
INSTRUCTOR'S RESOURCE SHEET 9
(1 DAY)

# BRIDGE RECTIFIER CHARACTERISTICS

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| | |
|---|---|
| **Essential Elements:** | Common: 6A, 6B, 8C, 9A, 9B<br>Specific: 1, 3, 10 |
| **TAAS Objectives:** | Mathematics: C 1, 4<br>Language Arts: RC 4, 5; WC 1 |

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## Activity Summary

This activity is designed to provide students the opportunity to investigate the characteristics of a bridge rectifier circuit. Four semiconductor junction diodes will be used as the rectifying devices. This activity will use a center-tapped, step-down transformer as the power source. An oscilloscope and a multimeter will be used to test the characteristics of the bridge rectifier circuit.

## Teaching Tips

1. Read through the activity before beginning it.
2. Reproduce activity sheets for each student, or lab group, before the activity.
3. Organize all equipment all equipment and supplies before the activity.

## Instructional Strategy

- Explain the construction of a semiconductor junction diode.
- Explain and demonstrate the operation of a diode in an alternating current circuit.
- Explain and demonstrate the construction of a bridge rectifier circuit using a schematic diagram.
- Explain and demonstrate the current flow path for a bridge rectifier circuit.
- Explain the testing procedures for a bridge rectifier using a multimeter and an oscilloscope.

## Equipment/Supplies

1. 12.6V center-tapped, step-down transformer
2. Four 1N4001 diodes
3. No. 47 incandescent lamp with lamp holder
4. Proto-board with connecting wires
5. Analog, or digital, multimeter
6. B&K 1405 oscilloscope

## Evaluation Key

1. Instructor evaluation of student's ability to follow the procedures of the activity sheet.
2. Instructor evaluation of student's ability to recognize the components used in a bridge rectifier circuit.
3. Instructor evaluation of student's ability to construct a bridge rectifier circuit on a proto-board using a schematic diagram.
4. Instructor evaluation of student's ability to explain the rectification properties of a bridge rectifier.
5. Instructor evaluation of student's ability to obtain desired bridge rectifier circuit information from the voltmeter function of the multimeter.
6. Instructor evaluation of student's ability to obtain desired bridge rectifier circuit information from an oscilloscope.
7. Instructor evaluation of student's ability to follow safety guidelines established for test equipment and voltage source.

# BRIDGE RECTIFIER CHARACTERISTICS

*Experiment with the characteristics of a bridge rectifier circuit.*

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## Objectives

- To identify the components of the bridge rectifier circuit
- To construct a bridge rectifier circuit
- To identify the alternating current rectification properties of a bridge rectifier circuit.
- To operate the voltmeter function of a multimeter to given standards when testing bridge rectifier circuit characteristics
- To operate the oscilloscope to given standards when testing bridge rectifier circuit characteristics
- To identify the operational characteristics of a diode in a bridge rectifier circuit

## Vocabulary/Concepts Reinforced

- Junction diode
- Rectifier
- Full-wave rectifier
- Bridge rectifier
- Pulsating direct current
- Center-tapped, step-down transformer

## Equipment/Supplies

- 12.6V center-tapped, step-down transformer
- Four 1N4001 diodes
- No. 47 incandescent lamp with lamp holder
- Proto-board with connecting wires
- Analog, or digital, multimeter
- B&K 1405 oscilloscope

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## Introduction

A bridge rectifier is a full-wave rectifier that uses four diodes to convert alternating current to pulsating direct current. A bridge rectifier does not require the center-tapped transformer that is needed for a two diode full-wave rectifier. A center-tapped, step-down transformer is used in the circuit for this activity to lower the output voltage to an appropriate level for the circuit components. A full-wave rectifier circuit doubles the pulsating direct current output of a half-wave rectifier. A full-wave rectifier can use both alternations of an alternating current sine wave to produce pulsating direct current.

In the circuit used in this activity, current flows in forward bias through D3, through the load, through D2, and back to the transformer during the positive alternation of the alternating current source. Current flows forward bias through D1, through the load, through D4, and back to the transformer during the negative alternation of the alternating current source. The current flow through the load travels in the same direction during both alternations of the sine wave. Full-wave, pulsating direct current is produced across the load.

A bridge rectifier is a very efficient power supply with a high power output. A bridge rectifier is a widely use full-wave rectifier circuit because it does not require the use of a center-tapped transformer. The use of a center-tapped transformer can be a disadvantage because of its size, weight, and cost.

This activity will demonstrate the characteristics of a bridge rectifier circuit. The voltmeter function of a multimeter will be used to test the input voltage provided by the center-tapped, step-down transformer and the output voltage produced by the bridge rectifier circuit. The oscilloscope will also be used to compare the input voltage waveform provided by the center-tapped, step-down transformer and the output voltage waveform produced by the bridge rectifier.

**Procedure**

1. Locate the proto-board with connecting wires, center-tapped, step-down transformer, four diodes, and lamp with lamp holder at the lab station.
2. Construct the circuit in **Figure 1** on the proto-board. Connect the diodes in the direction shown on the schematic diagram.
3. Plug the transformer cord into the receptacle.
4. Does the lamp produce light? Why does this result occur?

5. Turn on the oscilloscope.
6. Set the SWEEP RANGE setting to the 10-100 position.
7. Set the V. ATT setting to the 1/100 position.
8. Set the AC/DC setting to the DC position.
9. Attach the oscilloscope probes to the transformer terminals connected to the circuit at **Test Points A and B**. Draw the waveform.

10. Observe the waveform produced across the lamp by connecting the GROUND probe of the oscilloscope to **Test Point D** and the VERT INPUT probe of the oscilloscope to **Test Point C.** Draw the waveform.

11. How does the waveform produced by the transformer in **Step 9** compare to the waveform observed across the lamp in **Step 10**? Why does this result occur?

12. Set the multimeter to the proper AC voltmeter range to measure the voltage output of the transformer terminals attached to the circuit.
13. Measure and record the voltage at the transformer terminals at **Test Points A** and **B**.

$V_{T1}$ =_______________V

14. Set the multimeter to the proper DC voltmeter range to measure the voltage drop across the lamp.

15. Connect the positive probe of the multimeter to **Test Point C** and the negative probe of the multimeter to **Test Point D**. Measure and record the voltage drop across the lamp.

$V_{LAMP1} =$ ________________V

16. How does the alternating current voltage produced by the transformer measured in **Step 13** compare to the direct current voltage drop across the lamp measured in **Step 15**? Why does this result occur?

17. Unplug the transformer, and disconnect the circuit.
18. Turn off the multimeter and the oscilloscope.

**Evaluation**

1. Draw the schematic diagram for a bridge rectifier circuit.
2. Trace the path for current flow through the bridge rectifier circuit during each alternation of the alternating current flow produced by the transformer.

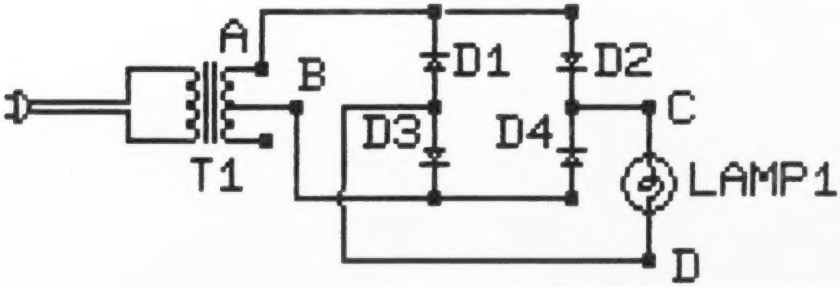

Fig. 1. Bridge rectifier

# FULL-WAVE VOLTAGE DOUBLER CHARACTERISTICS

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| | |
|---|---|
| **Essential Elements:** | Common: 6A, 6B, 8C, 9A, 9B<br>Specific: 1, 3, 10 |
| **TAAS Objectives:** | Mathematics: C 1, 4; O 1, 2<br>Language Arts: RC 4, 5; WC 1 |

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## Activity Summary

This activity is designed to provide students the opportunity to investigate the characteristics of a full-wave voltage doubler circuit. Two semiconductor junction diodes and two electrolytic capacitors will be used as the voltage doubling components. This activity will use a center-tapped, step-down transformer as the power source. An oscilloscope and a multimeter will be used to test the characteristics of the full-wave voltage doubler circuit.

## Teaching Tips

1. Read through the activity before beginning it.
2. Reproduce activity sheets for each student, or lab group, before the activity.
3. Organize all equipment and supplies before the activity.

## Instructional Strategies

- Explain and demonstrate the operation of a diode in an alternating current circuit.
- Explain and demonstrate the operation of an electrolytic capacitor.
- Explain and demonstrate the construction of a full-wave voltage doubler circuit using a schematic diagram.
- Explain and demonstrate the current flow path for a full-wave voltage doubler circuit.
- Explain the testing procedure for a full-wave voltage doubler circuit using a multimeter and an oscilloscope.

## Equipment/Supplies

1. 12.6V center-tapped, step-down transformer
2. Two 1N4001 diodes
3. Two 1,000 microfarad electrolytic capacitors
4. 470-ohm, 2-watt resistor
5. Single-pole switch
6. Proto-board with connecting wires
7. Analog, or digital, multimeter
8. B&K 1405 oscilloscope

## Evaluation Key

1. Instructor evaluation of student's ability to follow the procedures of the activity sheet.
2. Instructor evaluation of student's ability to recognize the components used in a full-wave voltage doubler circuit.
3. Instructor evaluation of student's ability to construct a full-wave voltage doubler circuit on a proto-board using a schematic diagram.
4. Instructor evaluation of student's ability to explain the rectification and voltage doubling properties of a full-wave voltage doubler circuit.

5. Instructor evaluation of student's ability to obtain desired full-wave voltage doubler circuit information from the voltmeter function of the multimeter.
6. Instructor evaluation of student's ability to obtain desired full-wave voltage doubler circuit information from an oscilloscope.
7. Instructor evaluation of student's ability to follow safety guidelines established for test equipment and voltage source.

# FULL-WAVE VOLTAGE DOUBLER CHARACTERISTICS

*Experiment with the characteristics of a full-wave voltage doubler circuit.*

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## Objectives

- To identify the components of the full-wave voltage doubler circuit
- To construct a full-wave voltage doubler circuit
- To identify the alternating current rectification properties of a full-wave voltage doubler circuit
- To operate the voltmeter function of a multimeter to given standards when testing full-wave voltage doubler circuit characteristics
- To operate the oscilloscope to given standards when testing full-wave voltage doubler circuit characteristics
- To identify the operational characteristics of a diode in a full-wave voltage doubler circuit
- To identify the operational characteristics of an electrolytic capacitor in a full-wave voltage doubler circuit

## Vocabulary/Concepts Reinforced

- Voltage doubler
- Full-wave voltage doubler
- Junction diode
- Rectifier
- Full-wave rectifier
- Electrolytic capacitor
- Pulsating direct current
- AC ripple
- Sawtooth waveform

## Equipment/Supplies

- 12.6V center-tapped, step-down transformer
- Two 1N4001 diodes
- Two 1,000 microfarad electrolytic capacitors
- 470-ohm, 2-watt resistor
- Single-pole switch
- Proto-board with connecting wires
- Analog, or digital, multimeter
- B&K 1405 oscilloscope

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## Introduction

A voltage doubler circuit increases the output voltage of a rectifier circuit without the use of a step-up transformer. A full-wave voltage doubler uses two semiconductor junction diodes and two electrolytic capacitors to rectify alternating current and increase the voltage output. A center-tapped, step-down transformer is used in the circuit for this activity to lower the output voltage to an appropriate level for the circuit components.

The two diodes of a full-wave voltage doubler circuit use both alternations of an alternating current sine wave to produce full-wave pulsating direct current. The two electrolytic capacitors perform two functions in the full-wave voltage doubler circuit. The capacitors charge and discharge to filter out AC ripple, or the alternating rectifier. The charging and discharging action of the capacitors when the pulsating direct current voltage increases or decreases produces a sawtooth waveform. The charging and discharging action of the capacitors also increases the voltage output across the load of the circuit.

Care must be taken when constructing a full-wave voltage doubler circuit. The diodes must be placed in the circuit with the anode and cathode terminals facing the direction shown in the schematic diagram. Electrolytic capacitors have a marked positive and negative terminal. Electrolytic capacitors must also be placed in the circuit in the direction shown in the schematic diagram.

In the circuit used for this activity, C1 charges through D1 during the positive alternation of the alternating current source. Capacitor C1 charges to the peak value of the alternating current source. During the negative alternation of the alternating current source, C2 charges through D2. Capacitor C2 will also charge to the peak value of the alternating current source. Capacitors C1 and C2 are connected in a series-aiding configuration, which allows the sum of the two capacitor charges to be applied to the load. This statement can be expressed by the following mathematical equation.

$$V_{R_L} = V_{C_1} + V_{C_2}$$

A full-wave voltage doubler circuit can come close to producing three times the alternating current input voltage. The major advantage of a full-wave voltage doubler circuit is that it eliminates the use of a step-up transformer. A transformer adds size, weight, and cost to an electronic circuit. The major disadvantage of a full-wave voltage doubler is that its voltage drops rapidly when the amount of load is increased in the circuit.

This activity will demonstrate the characteristics of a full-wave voltage doubler circuit. The voltmeter function of a multimeter will be used to test the input voltage provided by the center-tapped, step-down transformer and the output voltage produced by the full-wave voltage doubler circuit. The oscilloscope will also be used to compare the input voltage waveform provided by the center-tapped, step-down transformer and the output voltage waveform produced by the full-wave voltage doubler circuit.

## Procedure

1. Locate the proto-board with connecting wires, center-tapped, step-down transformer, switch, two diodes, two electrolytic capacitors, and 470-ohm resistor at the lab station.
2. Construct the circuit in **Figure 1** on the proto-board. Connect the diodes and electrolytic capacitors in the direction shown on the schematic diagram.
3. Turn the circuit switch to the "on" position.
4. Turn on the oscilloscope.
5. Set the SWEEP RANGE setting to the 10-100 position.
6. Set the V. ATT setting to the 1/100 position.
7. Set the AC/DC setting to the DC position.
8. Attach the oscilloscope probes to the transformer terminals at **Test Points A** and **B**. Draw the waveform.

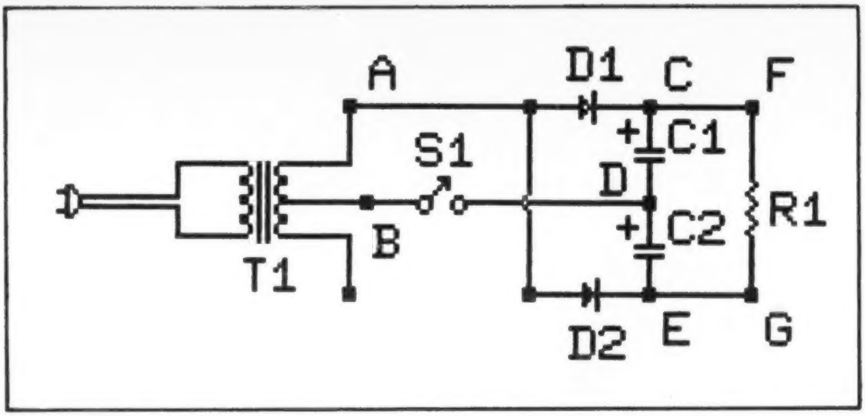
A
D1
C
F
S1
C1
D
R1
C2
B
T1
D2
E
G

Fig. 1. Full-wave voltage doubler

9. Observe the waveform produced across C1 by connecting the GROUND probe of the oscilloscope to **Test Point D** and the VERT INPUT probe of the oscilloscope to **Test Point C**. Draw the waveform.

10. Observe the waveform produced across C2 by connecting the GROUND probe of the oscilloscope to **Test Point E** and the VERT INPUT probe of the oscilloscope to **Test Point D**. Draw the waveform.

11. How does the waveform produced across C1 observed in **Step 9** compare to the waveform produced across C2 observed in **Step 10**?

12. Observe the waveform produced across the resistor by connecting the GROUND probe of the oscilloscope to **Test Point G** and the VERT INPUT probe of the oscilloscope to **Test Point F**. Draw the waveform.

13. How does the waveform produced by the transformer observed in **Step 8** compare to the waveform observed across the resistor in **Step 12**? Why does this result occur?

14. How does the waveform produced across C1 and C2 in **Steps 9** and **10** compare to the waveform observed across the resistor in **Step 12**? Why does this result occur?

15. Set the multimeter to the proper AC voltmeter range to measure the voltage output of the transformer terminals attached to the circuit.
16. Measure and record the voltage at the transformer terminals at **Test Points A** and **B**.

$V_{T1}$ = __________ V

17. Set the multimeter to the proper DC voltmeter range to measure the voltage level across each of the capacitors.
18. Connect the positive probe of the multimeter to **Test Point C** and the negative probe of the multimeter to **Test Point D**. Measure and record the voltage level across C1.

$V_{C1}$ = __________ V

19. Connect the positive probe of the multimeter to **Test Point D** and the negative probe of the multimeter to **Test Point E**. Measure and record the voltage level across C2.

$V_{C2}$ = __________V

20. Using the voltage values for C1 and C2 measured in **Steps 18** and **19** calculate the voltage applied to R1.

$V_{R1} = V_{C1} + V_{C2}$

$V_{R1}$ = __________V

21. Connect the positive probe of the multimeter to **Test Point F** and the negative probe of the multimeter to **Test Point G**. Measure and record the voltage level across R1.

$V_{R1}$ = __________V

22. How does the voltage applied to R1 calculated in **Step 20** compare to the voltage applied to R1 measured in **Step 21**?

23. How does the alternating current voltage produced by the transformer measured in **Step 16** compare to the direct current voltage applied to the resistor measured in **Step 22**? Why does this result occur?

24. Turn the circuit switch to the "off" position. Unplug the transformer, and disconnect the circuit.
25. Turn off the multimeter and the oscilloscope.

**Evaluation**
See your instructor for evaluation procedure.

# GENERAL INTRODUCTION TO THE A-BUS

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*General introduction to the A-BUS as used in this laboratory activities guide*

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**Activity Summary**
A number of the laboratory activities in this guide (Modules 13-21) make use of the Alpha Products A-BUS interface system for personal computers. This system contains a variety of inexpensive and easy-to-use interface cards that can be used with a variety of personal computers including the Apple II series, IBMs and IBM compatibles, Commodore 64, and the Tandy line.

The A-BUS system consists of (1) an A-BUS adapter that plugs into a personal computer, (2) a cable to link the adapter card to the interface cards, and (3) a selection of A-BUS cards that perform various interface functions. The same interface cards are used regardless of the computer. Thus, when changing from one computer model to another, all that you need to change is the adapter card. The cards are powered by wall plug transformers that supply 12 volts DC to the cards, making them very safe for laboratory experimentation.

Some of the interface cards supplied by Alpha for the A-BUS are relay card, isolated digital input card, 8-bit analog input card, dual stepper motor controller, real time clock card, touchtone decoder card, 12-bit analog input card, analog output card, and 24-line digital I/O card. These provide a wide variety of possibilities in studying computer interfaces from the ground up.

The A-BUS interface cards used in the activities in this guide are (1) the relay card (RE-140), (2) the isolated digital input card (IN-141), (3) the 8-channel 8-bit analog input card (AD-142), and (4) the dual stepper motor controller (ST-143).

**Teaching Tips**
Each of the A-BUS cards is supplied with a user's manual. These manuals present a straightforward description of the card and the programming necessary to use it. Most are 10 to 15 pages in length and include a complete schematic of the circuit used on the card. In addition, there is an A-BUS Overview manual and manuals for each computer adapter card.

> **Safety Note**: The A-BUS interface cards are single-sided printed circuit boards with the connections exposed on the bottom. Be very careful about laying the boards down on anything that might create a short between the traces. Screwdrivers, pliers, and especially small nuts are all bad news for the cards. Any one of these can create a short and destroy the card or even the adapter card in the computer. You might consider making an insulating cover for the bottom of boards or coating them with a nonconducting material.

The following are some suggestions on using each of the cards:

**Relay Card (RE-140)**

- The relays on the card are designed for a maximum of 3 amp at 125 VAC. Do not exceed these ratings. Since high voltage (>20 volts) is not a good idea in a student lab, the most important rating is the 3-amp limit regardless of voltage. Also be careful with inductive loads (motors and relays) and surge-type loads (large incandescent lamps) that draw near the 3 amp.

- **DO NOT** have any type of potentially dangerous equipment (rockets, power tools, etc.) connected to the card when first powering up because sometimes one or more of the relays will be energized on. This could be dangerous to people or equipment if it is unexpected. A short program in BASIC or using an immediate command can be used to turn off the relays. For example, when the adapter card is in slot 1 of an Apple II computer, the command POKE 49408,0 will turn off all the relays.

### Digital Input Card (IN-141)

- Use the power supply provided with the card. Getting total isolation is rarely needed and requires permanent changes on the card.

### 8-Channel 8-Bit Analog Input Card (AD-142)

- Be careful not to short the +5 volt and ground terminals together. This will shut down the voltage regulator on the card and could damage it. It is perfectly alright to connect any of the input terminals to +5 volts or ground directly.
- If the readings from the card are not consistent ("jumpy"), try adding a little delay between starting the A to D conversion and reading the input. A timing loop in BASIC like FOR Z = 1 TO 50 : NEXT Z is usually enough. Try it first without the delay.
- Don't play with the calibration adjustments until you have some experience with the card.

### Dual Stepper Motor Controller (ST-143)

- While it is possible to use almost any small stepper motor with the controller, you will get the best (and easiest) results with the motors supplied by Alpha.
- If a motor "jitters" but doesn't want to move, try (1) checking the sequence of commands being sent to the motor, (2) checkingthe connections between the motor and the controller, and (3) slowing down the stepping rate.

## Instructional Strategy

The A-BUS activities are designed to provide students with the bridge between electronic construction, interfacing, and computer applications. In every A-BUS activity, there is something that must be built or wired up and some simple computer programming to achieve the finished goal. The programming skills are minimal and should be of little problem for anyone who has had a good computer literacy course in which the BASIC language was introduced. Of course, some students will be better programmers, and some will have better hand skills. For this reason, a team or group approach is recommended for most of the A-BUS activities. This allows for an efficient division of labor.

## Equipment/Supplies

The complete A-BUS system is available from Alpha Products at the address below. For $10 they will send you a copy of the user's manuals for all of their products.

Alpha Products
242-M West Ave.
Darien, CT 06820
(203) 656-1806

# SOURCES OF ELECTRONIC COMPONENTS

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*Where you can get electronic components quickly and cheaply*

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### Activity Summary

In order to carry out Modules 13-21 in this guide, you will need to obtain various electronic components. If you need something fast, you should try your local Radio Shack or similar consumer electronics store. Sometimes, the local store may not have what you want in the quantities needed or at the best price. The solution to this dilemma is mail order.

The companies listed below have proven themselves reliable over the years. Some specialize in certain components, so each reference is followed by a short description of their strong points.

### Helpful Tips

- Get a catalog from each supplier. All will send one, if you write. Catalogs are your best source of what suppliers have, and they can also give you ideas about activities for your students.
- Be sure you know what you are ordering, especially with the surplus suppliers. It's a shame to get something that you "thought" would work only to find it's the wrong voltage, size, or whatever.
- Be careful when ordering small quantities. Sometimes the shipping can cost more than the parts.
- It's generally best not to accept back orders. Again, a small item on back order can cost more to ship separately than it is worth. Most of the best companies can tell you over the phone if they have the parts in stock.
- If you can, use a credit card and the 800 number to order. This will allow you to ask about stock and to get the quickest service.

### General Electronic Components

| | |
|---|---|
| Digi-Key Corp.<br>P.O. Box 677<br>Thief River Falls, MN 56701<br>(800) 344-4539 | Wide variety of basic components, ranging from resistors to digital integrated circuits. They are good in the area of connectors, plugs etc. Can always tell you over the phone if they have the part. |
| Mouser Electronics<br>2401 Highway 287 N.<br>Mansfield, TX 76065<br>(800) 346-6873 | Wide variety of basic components. They are good in the area of transistors, switches, and other hardware. Not always sure whether they have a part, however. |
| Kelvin Electronics<br>7 Fairchild Ave.<br>Plainview, NY 11803<br>(800) 645-9212 | Wide variety of components, instruments, and even kits. Some parts are surplus (not used), and their selection varies somewhat. You can find a bargain sometimes. |
| Arrow Electronics<br>manufacturers). 25 Hub Dr.<br>Melville, NY 11747-9828<br>(800) 932-7769 | Regular supplier to OEMs (original equipment<br>They handle only the best, and most of the time the price is high. Minimum order is $25.00. |

### Electromechanical Components

C and H Sales
2176 E. Colorado Blvd
PO Box 5356
Pasadena, CA 91117-9988
(800) 325-9465

Good selection of surplus (some used) components such as motors, fans, and solenoid valves. Also many fluid power and mechanical components. Don't always know what they have, but prices are good.

H&R Corporation
They
401 E. Erie Ave.
Philadelphia, PA 19134
(215) 425-8870

Longtime supplier of surplus (some used) components.

have a little of everything. Their catalog comes out in parts four to six times a year, and you must have at least four of them to have the whole thing. Good prices, if you are very sure of what you are ordering.

### Printed Circuit Board Supplies

Kepro Circuit Systems, Inc.
630 Axminister Dr.
to
Fenton, MO 63026-2992
(800) 325-3878

Carry every type of materials and equipment you could want for making printed circuit boards. Ranges from bare board

chemicals to complete production facilities.

Bishop Graphics
5388 Sterling Center Dr.
The
Westlake Village, CA 91359
(818) 991-2600

Premier supplier of artwork and graphic materials for PCB layout. Almost any conceivable pattern for photo layout.

catalog has a technical section that is literally a textbook on PCB layout. Excellent.

### Computer Interfaces

John Bell Engineering, Inc.
400 Oxford Way
Belmont, CA 94002

Simple and inexpensive interfaces for IBM and Apple II series. These include a good parallel interface and A-D converter. Also builds good single board control computers.

MetraByte Corp.
440 Myles Standish Blvd.
line.
Taunton, MA 02780
(508) 880-3000

Broad selection of interfaces which can be used for data acquisition and control. Most are for the IBM (MS-DOS)

Very good equipment with prices to match.

### Computer Components and Integrated Circuits

JDR Microdevices
a
2233 Branham Lane
they San Jose, CA 95124
(800) 538-5000

Computer components from clones to interface cards. Also

very good selection of integrated circuits. Can tell you if have it.

ELECTRICITY/ELECTRONICS SYSTEMS
INSTRUCTOR'S RESOURCE SHEET 13
(2-3 DAYS)

# BINARY TO DECIMAL NUMBERS USING THE COMPUTER

---

**Essential Elements:** Common: 8, 9
Specific: 13
**TAAS Objectives:** Mathematics: C 1-2; O 1-3; PS 2-3
Language Arts: RC 1-5

---

## Activity Summary

Students examine binary numbers and their conversion from decimal numbers. The A-BUS relay card is used to demonstrate these conversions.

## Teaching Tips

- Point out the importance of binary numbers in digital electronics and computers.
- Carefully demonstrate the procedures for conversion of decimal to binary and binary to decimal numbers.
- To simplify the programming, have every student use the same slot in the Apple or port in the IBM. This will eliminate the problem of different base addresses.
- The introduction to the A-BUS system (Module 11) and the A-BUS user's manuals are invaluable references for all activities using the system.

## Instructional Strategy

This activity provides a "real world" demonstration of an otherwise academic and esoteric procedure. The A-BUS relay card displays binary numbers by turning on the appropriate LEDs. This makes binary numbers very visible.

## Equipment/Supplies

- A-BUS Relay Card RE-140, cable, and A-BUS interface card for Apple II or IBM.

## Evaluation Key

1. Write a program to convert a decimal number to binary on the relay card.
   The programs below display the binary number 1001 0110 (decimal 150) on the A-BUS relay card for approximately 5 seconds, then shut all LEDs off.
   The AppleSoft BASIC version of the program assumes that the A-BUS interface card is in slot 1, while the IBM BASICA or GW-BASIC version assumes that the interface card is set in the factory position (port 512).

**AppleSoft BASIC**

```
10  REM DISPLAY BINARY 1001 0110
20  TEXT : HOME
30  PRINT "DISPLAYING 1001 0110"
40  POKE  49408, 150
50  FOR Z = 0 TO 5000 : NEXT Z
60  POKE  49408, 0
```

**BASICA or GW-BASIC**

```
10  REM Display Binary 1001 0110
20  CLS
30  PRINT "Displaying 1001 0110"
40  OUT  512, 150
50  FOR Z = 0 TO 5000 : NEXT Z
60  OUT  512, 0
```

2. Use the relay card to count up slowly in binary from 0 to 255.

**AppleSoft BASIC**

```
10  REM BINARY COUNT UP
20  TEXT : HOME
30  PRINT "BINARY COUNTING UP"
40  FOR X = 0 TO 255
50  POKE 49408,X
60  FOR Z = 0 TO 2000 : NEXT Z
70  NEXT X
80  POKE 49408,0
```

**BASICA or GW-BASIC**

```
10  REM Binary Count Up
20  CLS
30  PRINT "Binary Counting Up"
40  FOR X = 0 TO 255
50  OUT  512,X
60  FOR Z = 0 TO 2000 : NEXT Z
70  NEXT X
80  OUT  512,0
```

*This program goes through the numbers once, then turns off the display and ends.

3. Use the relay card to display the binary equivalent of a decimal number entered from the keyboard.

**AppleSoft BASIC**

```
10  REM DISPLAY KEYBOARD NUMBER
20  TEXT : HOME
30  INPUT "ENTER A NUMBER -> " ; N
40  IF N < 0 OR N > 255 THEN 70
50  POKE 49408,N
60  GOTO 30
70  POKE 49408,0
```

**BASICA or GW-BASIC**

```
10  REM Display Keyboard Number
20  CLS
30  INPUT "Enter a Number -> " ; N
40  IF N < 0 OR N > 255 THEN 70
50  OUT  512,N
60  GOTO 30
70  OUT  512,0
```

*You must type the number, then press return. If a number greater than 255 or less than 0 is entered, the program turns off the relays and ends.

4. Write a program to display a binary number on the relay card, and have another student find which decimal number it represents by entering a "guess" on the keyboard.

**AppleSoft BASIC**

```
 10  REM BINARY GAME
 20  TEXT : HOME
 30  X = INT (RND(1) * 255)
 40  POKE 49408,X
 50  INPUT "ENTER DECIMAL  -> " ; N
 60  IF N < 0 OR N > 255 THEN 200
 70  IF N = X THEN 100
 80  PRINT "SORRY"
 90  GOTO 50
100  PRINT "CORRECT ANSWER"
110  GOTO 30
200  POKE 49408,0
```

**BASICA or GW-BASIC**

```
 10  REM Binary Game
 20  CLS
 30  X = INT (RND(1) * 255)
 40  OUT  512,X
 50  INPUT "Enter Decimal -> " ; N
 60  IF N < 0 OR N > 255 THEN 200
 70  IF N = X THEN 100
 80  PRINT "Sorry"
 90  GOTO 50
100  PRINT "Correct Answer"
110  GOTO 30
200  OUT  512,0
```

*You must type the number, then press return. If a number greater than 255 or less than 0 is entered, the program turns off the relays and ends.

# BINARY TO DECIMAL NUMBERS USING THE COMPUTER

*Use the A-BUS relay card to display binary numbers.*

---

**Objectives**

- To investigate the relationship between decimal and binary numbers
- To demonstrate the conversion of decimal to binary numbers using a computer interface
- To understand the importance of binary numbers in digital electronics

**Vocabulary/Concepts Reinforced**

- Base ten numbers (decimal)
- Base two numbers (binary)
- Programming computer interfaces to convert decimal values to binary

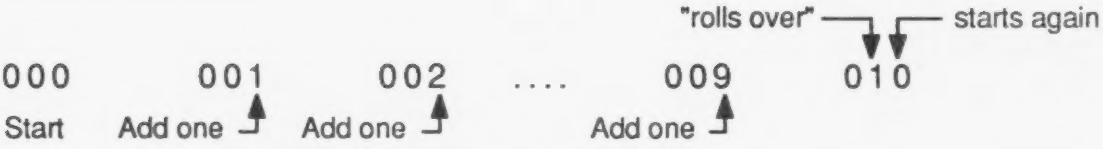
**Equipment/Supplies**

- A-BUS relay card, cable, and A-BUS interface card for Apple II or IBM

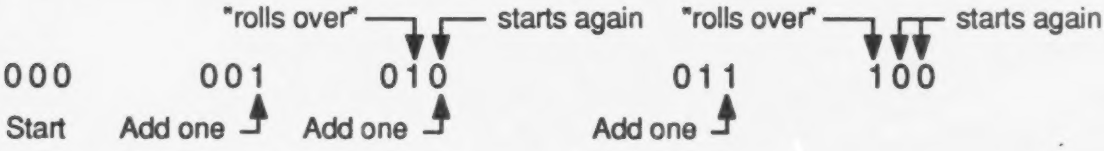
---

**Introduction**

We are all familiar with the decimal system of numbers. We use this system to count and do everyday mathematics. This system is based on ten unique numbers from 0 to 9. We can think of counting in our ordinary decimal or base 10 system in terms of a automobile odometer. When we start, all digits are 0. As we drive, the rightmost digit increases by one as we pass each mile so that we count from 0 to 9. As we drive past the 9th mile and on the 10th, the odometer will "roll over" to the next digit. The second rightmost digit becomes a 1, and the rightmost digit starts over and becomes a 0.



In the binary number system, only two numbers are used: 0 and 1. Counting in the binary system works just like counting in decimal except that we only have two unique numbers to work with, 0 and 1. Think about the mileage odometer again. When we start, all digits are 0. As we count up, the rightmost digit becomes a 1. Then, as we add one and move to the next number, the odometer "rolls over" to the next digit. The second rightmost becomes a 1, while the rightmost starts over at 0.



Because computers use binary numbers, it is important to be able to convert numbers from binary to decimal and back again.

First, conversion from binary to decimal. Each place or digit in binary numbers is a successive power of 2, so that the rightmost position is $2^0 = 1$, the second rightmost is $2^1 = 2$, and so on. This can most easily be seen using the chart below:

| Powers of two | $2^8$ | $2^7$ | $2^6$ | $2^5$ | $2^4$ | $2^3$ | $2^2$ | $2^1$ | $2^0$ |
|---|---|---|---|---|---|---|---|---|---|
| Decimal values | 256 | 128 | 64 | 32 | 16 | 8 | 4 | 2 | 1 |

In order to convert a number from binary to decimal, find the numbers in the chart that correspond to 1s in the binary number and add them together. This sum will be the equivalent decimal number.

|  | $2^8$ | $2^7$ | $2^6$ | $2^5$ | $2^4$ | $2^3$ | $2^2$ | $2^1$ | $2^0$ |  |
|---|---|---|---|---|---|---|---|---|---|---|
|  | 256 | 128 | 64 | 32 | 16 | 8 | 4 | 2 | 1 |  |
| Binary number | 0 | 0 | 1 | 0 | 1 | 0 | 0 | 1 | 1 |  |
| Conversion |  |  | 64 | + | 16 | + |  | 2 | + 1 | = 83 |

Conversion from decimal to binary. Each place in the binary number can be a 0 or a 1. Start from the *left*, and find the first decimal number in the powers of two chart that is not larger than the decimal value you wish to convert. Write down a *one* for that place in the binary number. Subtract the number from the chart from your original number. If the answer is smaller than the next number to the right in the chart, write down a *zero* for that binary place. Write down zeros until you come to a number that is smaller or equal in the chart. Write down a 1, and subtract the number from your answer. Continue with this procedure until you have filled in all the binary places.

*Example*: Convert 83 to a binary number.

83 is larger than 64 but smaller than 128 -> Put a 1 in binary 64 place.

|  | $2^8$ | $2^7$ | $2^6$ | $2^5$ | $2^4$ | $2^3$ | $2^2$ | $2^1$ | $2^0$ |
|---|---|---|---|---|---|---|---|---|---|
| Decimal values | 256 | 128 | 64 | 32 | 16 | 8 | 4 | 2 | 1 |
| Binary place values |  |  | 1 |  |  |  |  |  |  |

83 - 64 = 19

19 is smaller than 32 -> Put a 0 in binary 32 place.

|  |  |  |  |  |  |  |  |  |  |
|---|---|---|---|---|---|---|---|---|---|
| Decimal values | 256 | 128 | 64 | 32 | 16 | 8 | 4 | 2 | 1 |
| Binary place values |  |  | 1 | 0 |  |  |  |  |  |

19 is larger than 16 -> Put a 1 in binary 16 place.

|  |  |  |  |  |  |  |  |  |  |
|---|---|---|---|---|---|---|---|---|---|
| Decimal values | 256 | 128 | 64 | 32 | 16 | 8 | 4 | 2 | 1 |
| Binary place values |  |  | 1 | 0 | 1 |  |  |  |  |

19 - 16 = 3

3 is smaller than 8 -> Put a 0 in binary 8 place.

|  |  |  |  |  |  |  |  |  |  |
|---|---|---|---|---|---|---|---|---|---|
| Decimal values | 256 | 128 | 64 | 32 | 16 | 8 | 4 | 2 | 1 |
| Binary place values |  |  | 1 | 0 | 1 | 0 |  |  |  |

3 is smaller than 4 -> Put a 0 in binary 4 place.

|  |  |  |  |  |  |  |  |  |  |
|---|---|---|---|---|---|---|---|---|---|
| Decimal values | 256 | 128 | 64 | 32 | 16 | 8 | 4 | 2 | 1 |
| Binary place values |  |  | 1 | 0 | 1 | 0 | 0 |  |  |

3 is larger than 2 -> Put a 1 in binary 2 place.

| Decimal values | 256 | 128 | 64 | 32 | 16 | 8 | 4 | 2 | 1 |
|---|---|---|---|---|---|---|---|---|---|
| Binary place values | | | 1 | 0 | 1 | 0 | 0 | 1 | |

3 - 2 = 1

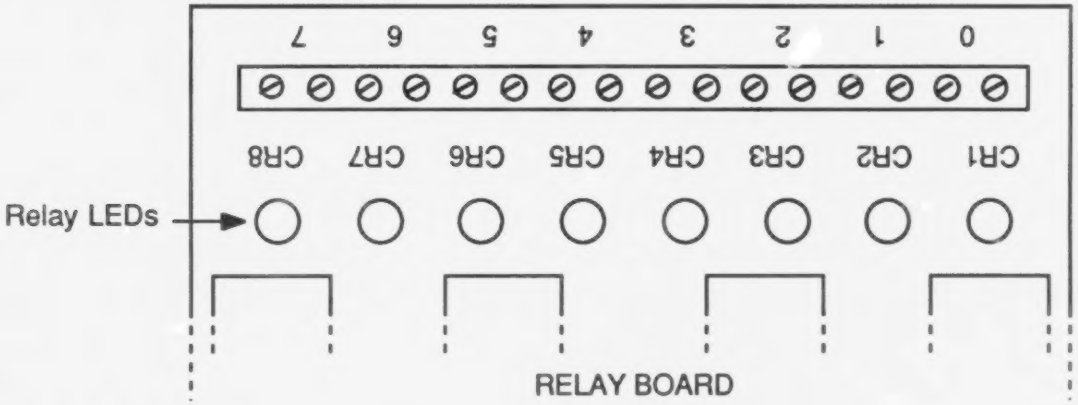
1 is equal to 1 -> Put a 1 in binary 1 place.

| Decimal values | 256 | 128 | 64 | 32 | 16 | 8 | 4 | 2 | 1 |
|---|---|---|---|---|---|---|---|---|---|
| Binary place values | | | 1 | 0 | 1 | 0 | 0 | 1 | 1 |

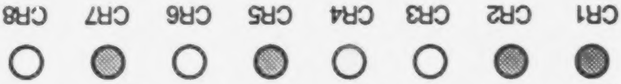
Answer: Decimal 83 equals binary 101 0011.

**Procedure**

1. Connect the A-BUS relay card to your computer using the A-BUS interface card and cable.
2. Test the relay card by entering the appropriate test program into your computer and running it.
3. By placing the card so that the CR8 LED is on the left (*upside down*), the relay indicator LEDs will be in the proper order of the binary digit places.
4. Do the evaluation problems.



Decimal 83 from the previous example would look like this when displayed on the relay card in binary: Binary = 101 0011



Decimal Values 128 64 32 16 8 4 2 1

*Programming the A-BUS relay card:*

- Each relay on the A-BUS card is activated by sending a decimal number to the I/O port. When a relay is activated, it will close the circuit to the display and turn on the corresponding LED indicator. The following list shows the number for each relay:

| Value | Relay | LED Indicator | Binary Digit Place |
|---|---|---|---|
| 1 | 0 | CR1 | 1 |
| 2 | 1 | CR2 | 2 |
| 4 | 2 | CR3 | 4 |
| 8 | 3 | CR4 | 8 |
| 16 | 4 | CR5 | 16 |
| 32 | 5 | CR6 | 32 |
| 64 | 6 | CR7 | 64 |
| 128 | 7 | CR8 | 128 |

- When a decimal number from 0 to 255 is sent to the computers I/O port and then to the relay card, it will be automatically converted to a binary number.
- The actual method of sending a number to the I/O port depends on the kind of computer you are using.

*For Apple II computers in AppleSoft BASIC:*

1. The slot holding the A-BUS interface card determines the "base address." These are:

| | |
|---|---|
| Slot 1 | 49408 |
| Slot 2 | 49664 |
| Slot 3 | 49920 |
| Slot 4 | 50176 |
| Slot 5 | 50432 |
| Slot 6 | 50688 |
| Slot 7 | 50944 |

2. A POKE statement is used to send the desired number to the A-BUS relay card. For example, if the interface card is in slot 1, a POKE 49408,6 will send a 6 to the A-BUS relay card, activate relays 1 and 2, and display a binary 110 on the indicator LEDs.
3. Test program in AppleSoft BASIC with A-BUS interface card in slot 1. Converts decimal 83 and displays a binary 0101 0011 for approximately 5 seconds, then turns all LEDs off.

```
10 TEXT : HOME
20 PRINT "TESTING A-BUS RELAY CARD"
30 POKE 49408, 83
40 FOR Z = 0 TO 5000: NEXT Z
50 POKE 49408, 0
```

*For IBM and compatible computers using BASICA or GW-BASIC:*

1. The interface card in the IBM is set for a particular I/O port. The ports that work best in most IBMs and compatibles are 512 to 576.
2. Use an OUT statement to send the desired number to the A-BUS relay card. For example, if the base port is 512, the statement OUT 0,6 will send a 6 to the A-BUS relay card, activate relays 1 and 2, and display a binary 110 on the indicator LEDs.
3. Test program in IBM BASICA or GW-BASIC with A-BUS interface card set for port address 512. Converts decimal 83 and displays an binary 0101 0011 for approximately 5 seconds, then turns all LEDs off.

```
10 CLS
20 PRINT "Testing A-BUS Relay Card"
30 OUT 512, 83
40 FOR Z = 0 TO 5000: NEXT Z
50 OUT 512, 0
```

## Evaluation

1. Write a program to convert a decimal number to binary on the relay card.
2. Use the relay card to count up slowly in binary from 0 to 255.
3. Use the relay card to display the binary equivalent of a decimal number entered from the keyboard.
4. Write a program to display a binary number on the relay card and have another student find which decimal number it represents by entering a "guess" on the keyboard.

## Support Materials

- Use the introduction to the A-BUS from this guide (Module 11)
- BASIC programming manual for Apple II or IBM

ELECTRICITY/ELECTRONICS SYSTEMS
INSTRUCTOR'S RESOURCE SHEET 14
(2-3 DAYS)

# NUMBER CONVERSIONS

---

**Essential Elements:** Common: 8, 9
Specific: 13
**TAAS Objectives:** Mathematics: C 1-2; O 1-3; PS 2-3
Language Arts: RC 1-5

---

## Activity Summary

Students practice methods of converting values to/from binary, decimal, and hexadecimal numbering systems.

## Teaching Tips

- Point out the importance of binary and hexadecimal numbers in digital and computer electronics.
- Emphasize the "odometer" method of counting in any numbering system. Demonstrate that each system "rolls over" at a different point.
- Show students how they can use the method to count using any base.
- Demonstrate how the procedures for conversion can be broken down into a series of simple steps.
- Many inexpensive scientific calculators can do the conversions for you.

## Instructional Strategy

This activity provides a set of rules to follow in counting and converting. The counting rules are "cookbook," but they work every time for any numbering system. The conversion methods work consistently for binary, decimal, and hexadecimal systems.

## Equipment/Supplies

- None

## Evaluation Key

1. 5
2. 42
3. 34
4. 239
5. 29
6. 2
7. 85
8. 401
9. 10111
10. 110110
11. 111000
12. 1001100
13. 1000001
14. 1111011
15. 11101011
16. 100110110
17. $5
18. $A
19. $22
20. $EF
21. $1D
22. $2
23. $55
24. $91B
25. 0010
26. 1110
27. 0100 1111
28. 0110 1110
29. 1110 1010
30. 1111 1111
31. 1111 1101
32. 1010 1101 1101

# NUMBER CONVERSIONS

*Practice making easy conversions from one numbering system to the other.*

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**Objectives**

- To investigate the relationship between decimal, hexadecimal, and binary numbers
- To demonstrate the conversion of decimal to binary numbers
- To demonstrate the conversion of binary to decimal numbers
- To demonstrate the conversion of hexadecimal to binary numbers
- To demonstrate the conversion of binary to hexadecimal numbers

**Vocabulary/Concepts Reinforced**

- Base ten numbers (decimal)
- Base two numbers (binary)
- Base sixteen numbers (hexadecimal)
- Conversion methods
- Bit
- Byte
- Nibble

**Equipment/Supplies**

- None

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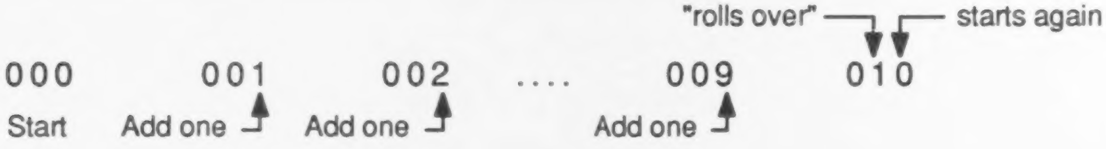
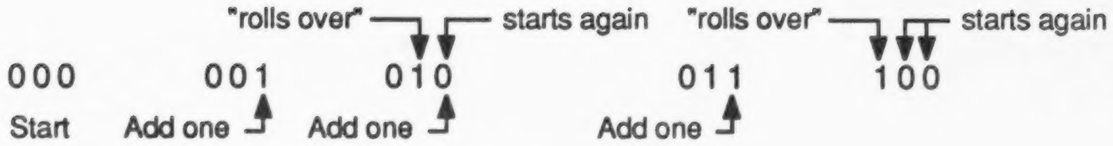
**Introduction**

**Decimal numbers.** We are all familiar with the decimal system of numbers. We use this system to do everyday counting and mathematics. The decimal system is based on ten unique numbers from 0 to 9. You can think of counting in our ordinary decimal or base 10 system in terms of a automobile odometer. When you start, all digits are 0. As you drive, the rightmost digit increases by one as you pass each mile so that you count from 0 to 9. As you drive past the 9th mile and on to the 10th, the odometer will "roll over" to the next digit. The second rightmost digit becomes a 1, and the rightmost digit starts over and becomes a 0.



**Binary numbers.** In the binary number system, only two numbers are used: 0 and 1. Counting in the binary system works just like counting in decimal except that you only have two unique numbers to work with, 0 and 1. Think about the mileage odometer again. When you start, all digits are 0. As you count up, the rightmost digit becomes a 1. Then, as you add one and move to the next number, the odometer "rolls over" to the next digit. The second rightmost digit becomes a 1, while the rightmost digit starts over at 0.

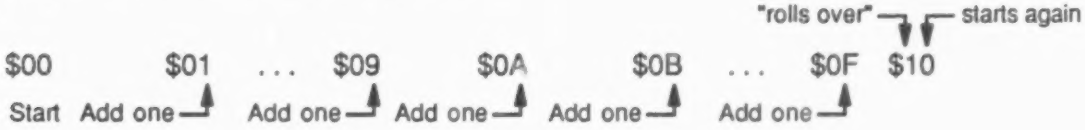


Binary numbers are extremely important in digital electronics because the switch is the simplest electrical circuit that can be built. A switch is in one of two positions: on or off. In digital electronics and computers, a switch that is *on* is said to have a value of 1, while a switch that is *off* has a value of 0. By using a series of simple switches (either mechanical or electronic), information and data can be stored or manipulated.

**Hexadecimal numbers.** Binary numbers are hard for humans to handle because it takes so many digits (places) to represent a number of any size. Hexadecimal or base 16 numbers are an important solution to this problem. But why base 16? Mainly because many microcomputers and digital circuits use eight binary digits (or bits) to depict numbers or other data. These eight bits are called a ***byte***. The number of decimal numbers that can be depicted using an given number of binary bits is equal to $2^{\text{number of bits}}$. So, for eight bits, you can represent 256 ($2^8$) decimal numbers or 0 to 255. One half a byte (4 bits) is called a ***nibble***. A binary nibble can be used to represent 16 numbers ($2^4 = 16$). If you had a numbering system that would allow you to represent each nibble with one digit, a byte would always be two digits long—one for each four-bit nibble. Hexadecimal (base 16) numbers let you do this, since they can represent all the numbers from 0 to 15 with one digit.

The base of a numbering system determines the number of unique symbols that must be used in that system. Our common decimal (base 10) system uses ten unique symbols to represent any number: 0 1 2 3 4 5 6 7 8 9. The binary system (base 2) requires only two unique symbols: 0 and 1. Hexadecimal numbers (base 16), then, require that you have sixteen unique symbols. This is done by "borrowing" some of the letters from the alphabet. The hexadecimal symbols are: 0 1 2 3 4 5 6 7 8 9 A B C D E F. There are sixteen; count them. Because hexadecimal numbers use some of the same symbols as decimal numbers, yet have very different values, they are usually indicated with a $ or H. For example: $3F or 3FH.

Counting with hexadecimal numbers is just like counting in decimal until you get to nine. Instead of "rolling" over, the next number is A. You only roll over when you get to F, where the next number is 10.



This makes the hexadecimal count from $0 to $21:

0 1 2 3 4 5 6 7 8 9 A B C D E F 10
11 12 13 14 15 16 17 18 19 1A 1B 1C 1D 1E 1F 20 21

**Procedure**

**Binary to decimal conversion.** Each place or digit in binary numbers is a successive power of 2, so that the rightmost position is $2^0 = 1$, the second rightmost is $2^1 = 2$, and so on. This can most easily be seen using the chart below:

| Powers of two | $2^7$ | $2^6$ | $2^5$ | $2^4$ | $2^3$ | $2^2$ | $2^1$ | $2^0$ |
|---|---|---|---|---|---|---|---|---|
| Decimal values | 128 | 64 | 32 | 16 | 8 | 4 | 2 | 1 |

In order to convert a number from binary to decimal, find the numbers in the chart that correspond to 1s in the binary number and add them together. This sum will be the equivalent decimal number.

*Example*: Convert 0101 0011 to decimal.

| | $2^7$ | $2^6$ | $2^5$ | $2^4$ | $2^3$ | $2^2$ | $2^1$ | $2^0$ | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | 128 | 64 | 32 | 16 | 8 | 4 | 2 | 1 | | |
| Binary number | 0 | 1 | 0 | 1 | 0 | 0 | 1 | 1 | | |
| Conversion | | 64 | + | 16 | + | | 2 + | 1 | = | 83 |

**Decimal to binary conversion.** Each place in the binary number can be a 0 or a 1. Start from the *left*, and find the first decimal number in the powers of two chart that is not larger than the decimal value you wish to convert. Write down a one for that place in the binary number. Subtract the number from the chart from your original number. If the answer is smaller than the next number to the right in the chart, write down a zero for that binary place. Write down zeros until you come to a number that is smaller or equal in the chart. Write down a 1, and subtract the number from your answer. Continue with this procedure until you have filled in all the binary places.

*Example*: Convert 94 to binary.

94 is more than 64 but less than 128 -> Put a 1 in binary 64 place.

| | $2^7$ | $2^6$ | $2^5$ | $2^4$ | $2^3$ | $2^2$ | $2^1$ | $2^0$ |
|---|---|---|---|---|---|---|---|---|
| Decimal values | 128 | 64 | 32 | 16 | 8 | 4 | 2 | 1 |
| Binary place values | | 1 | | | | | | |

94 - 64 = 30

30 is less than 32 -> Put a 0 in binary 32 place.

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Decimal values | 128 | 64 | 32 | 16 | 8 | 4 | 2 | 1 |
| Binary place values | | 1 | 0 | | | | | |

30 is more than 16 -> Put a 1 in binary 16 place.

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Decimal values | 128 | 64 | 32 | 16 | 8 | 4 | 2 | 1 |
| Binary place values | | 1 | 0 | 1 | | | | |

30 - 16 = 14

14 is more than 8 -> Put a 1 in binary 8 place.

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Decimal values | 128 | 64 | 32 | 16 | 8 | 4 | 2 | 1 |
| Binary place values | | 1 | 0 | 1 | 1 | | | |

14 - 8 = 6

6 is more than 4 -> Put a 1 in binary 4 place.

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Decimal values | 128 | 64 | 32 | 16 | 8 | 4 | 2 | 1 |
| Binary place values | | 1 | 0 | 1 | 1 | 1 | | |

6 - 4 = 2

2 is equal to 2 -> Put a 1 in binary 2 place.

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| **Decimal values** | 128 | 64 | 32 | 16 | 8 | 4 | 2 | 1 |
| **Binary place values** | | 1 | 0 | 1 | 1 | 1 | 1 | |

2 - 2 = 0
0 is less than 1 -> Put a 0 in binary 1 place.

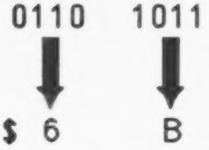
| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| **Decimal values** | 128 | 64 | 32 | 16 | 8 | 4 | 2 | 1 |
| **Binary place values** | | 1 | 0 | 1 | 1 | 1 | 1 | 0 |

*Answer*: Decimal 94 equals binary 101 1110.

**Binary to hexadecimal conversion.** When going from binary to hexadecimal, the important thing to remember is that each group of four binary digits (bits) will convert to one hexadecimal digit. So take any binary number, one nibble at a time. The easiest way to find the hexadecimal equivalent of a four-bit binary number is to use a table at least until you get them memorized. Below is the table and an example of binary to hexadecimal conversion.

| BINARY | HEX | BINARY | HEX | BINARY | HEX | BINARY | HEX |
|---|---|---|---|---|---|---|---|
| 0000 | 0 | 0100 | 4 | 1000 | 8 | 1100 | C |
| 0001 | 1 | 0101 | 5 | 1001 | 9 | 1101 | D |
| 0010 | 2 | 0110 | 6 | 1010 | A | 1110 | E |
| 0011 | 3 | 0111 | 7 | 1011 | B | 1111 | F |

*Example*: Convert the binary byte 0110 1011 to hexadecimal.
Look up each nibble in the table, and write down the matching hexadecimal value.

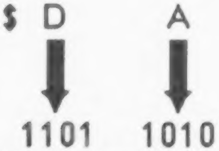


*Answer*: Binary 0110 1011 equals $6B.

**Hexadecimal to binary conversion.** Each hexadecimal digit will result in four binary bits when converting hexadecimal to binary. You will have one nibble (4 bits) for each hexadecimal digit. Use the table given with the binary to hexadecimal conversion above.

*Example*: Convert the hexadecimal number $DA to binary.

Look up each hexadecimal digit in the table, and write down the matching binary value.



*Answer*: Hexadecimal $DA equals 1101 1010 in binary.

**Evaluation**

Convert the following binary numbers to their decimal equivalents:

1. 0101
2. 1010 10
3. 0010 0010
4. 1110 1111
5. 0001 1101
6. 0000 0010
7. 0101 0101
8. 1 1001 0001

Convert the following decimal numbers to their binary equivalents:

9. 23
10. 54
11. 56
12. 76
13. 65
14. 123
15. 235
16. 310

Convert the following binary numbers to their hexadecimal equivalents:

17. 0101
18. 1010
19. 0010 0010
20. 1110 1111
21. 0001 1101
22. 0000 0010
23. 0101 0101
24. 1001 0001 1011

Convert the following hexadecimal numbers to their binary equivalents:

25. $2
26. $E
27. $4F
28. $6E
29. $EA
30. $FF
31. $FD
32. $ADD

ELECTRICITY/ELECTRONIC SYSTEMS
INSTRUCTOR'S RESOURCE SHEET 15
(3-5 DAYS)

# SEVEN-SEGMENT DISPLAY

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**Essential Elements:** Common: 8-10
Specific: 11-14
**TAAS Objectives:** Mathematics: C 1-2; O 1; PS 2-3
Language Arts: RC 1-5

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## Activity Summary

Students construct a seven-segment display from pilot lamps, interface the display to a computer, and write programs to produce numbers from 0 to 9.

## Teaching Tips

- Point out the many applications for seven-segment displays, e.g., calculators, gas pumps, clocks, scoreboards, etc.
- Use this activity in conjunction with Activity 14, on number conversions.
- Emphasize the relationship between the schematic drawing of the circuit and the final display.
- Use a team approach to building and programming the display.
- To simplify the programming, have every student use the same slot in the Apple or port in the IBM. This will eliminate the problem of different base addresses.
- The introduction to the A-BUS system (Module 11) in this guide and the A-BUS user's manuals are invaluable references for all activities using the system.

## Instructional Strategy

This activity combines electrical/electronics construction skills, the mechanics of computer interfacing, and computer programming. Students are involved in all phases of the interfacing experience from the mechanics of wiring to programming. The activity lends itself to a team approach with some students doing the actual construction while others work primarily on the programming. The finished product is also one that is a good "show-off" piece for the class and the teacher's program.

## Equipment/Supplies

1. A-BUS relay card RE-140, cable, and A-BUS interface card for Apple II or IBM
2. Seven 12V pilot lamps
3. Seven fuse holders
4. Seven small wood screws to mount fuse holders
5. Soldering iron and solder
6. Screwdriver
7. A supply of solid conductor wire
8. A piece of thin plywood on which to mount the fuse holders

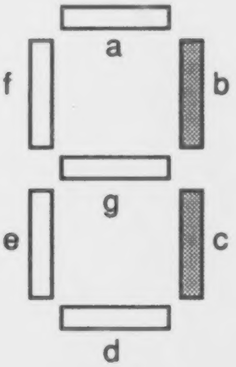
## Evaluation Key

1. Write a program to create one of the numbers from 0 to 9 on the display.

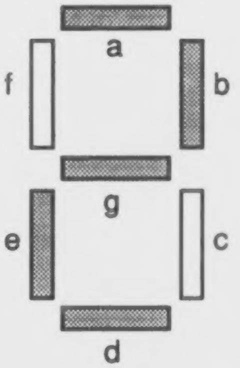
Each number on the display is created by (1) choosing the segments that will be lit; (2) summing the values of the relays corresponding to the segments; and (3) sending the value to the I/O port. For example, to display a 1, you need to light up segments b and c. The value for segment b is 4, and the value for segment c is 8, so 8 + 4 = 12. Send a 12 to the I/O port. The values for all the segments are listed below:

| Segment | Relay | Value |
|---|---|---|
| | 0 | 1 |
| a | 1 | 2 |
| b | 2 | 4 |
| c | 3 | 8 |
| d | 4 | 16 |
| e | 5 | 32 |
| f | 6 | 64 |
| g | 7 | 128 |

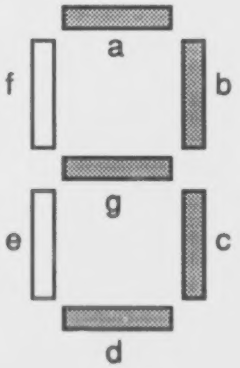
The summed values for each number are shown below. Variations on the numbers are left up to you.



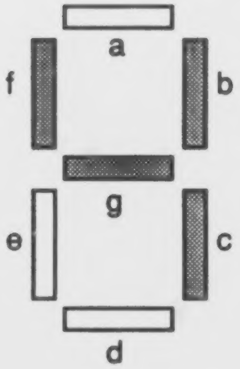
**12**



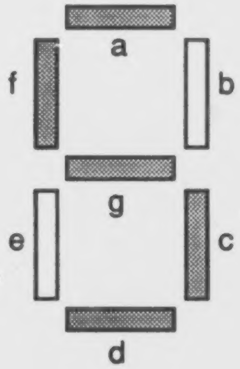
**182**



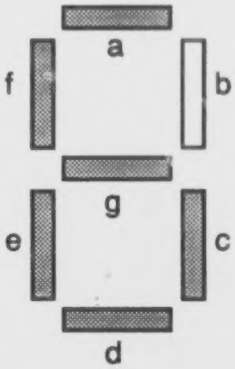
**158**



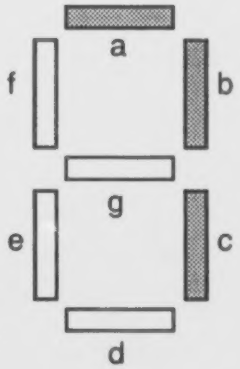
**204**



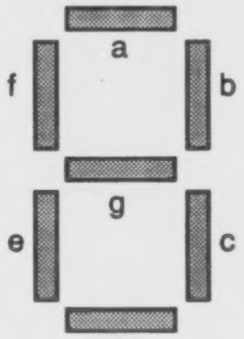
**218**



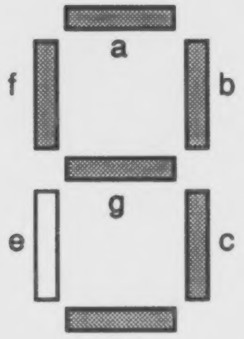
**250**



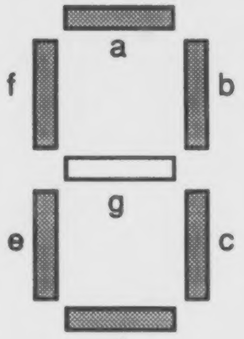
**14**



254



222



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The programs below create an 8 on the display. The AppleSoft BASIC version of the program assumes that the A-BUS interface card is in slot 1, while the IBM BASICA or GW-BASIC version assumes that the interface card is set in the factory position (port 512).

**AppleSoft BASIC**

```
 10  REM SEVEN-SEGMENT TEST
 20  TEXT : HOME
 30  PRINT "DISPLAYING THE NUMBER 8"
 40  POKE  49408, 254
 50  FOR Z = 0 TO 5000 : NEXT Z
 60  POKE  49408, 0
```

**BASICA or GW-BASIC**

```
 10  REM Seven-segment Test
 20  CLS
 30  PRINT "Displaying the Number 8"
 40  OUT  512, 254
 50  FOR Z = 0 TO 5000 : NEXT X
 60  OUT  512, 0
```

2. Use the display to count up slowly from 0 to 9.

**AppleSoft BASIC**

```
 10  REM SEVEN-SEGMENT COUNT UP
 20  TEXT : HOME
 30  DIM A(9)
 40  FOR X = 0 TO 9 : READ A(X) : NEXT X
 50  FOR Y = 0 TO 9
 60  POKE 49408,A(Y)
 70  FOR Z = 0 TO 5000 : NEXT Z
 80  NEXT Y
 90  DATA 126, 12, 182, 158, 204, 218,
     250, 14, 254, 222
100  POKE 49408, 0
```

**BASICA or GW-BASIC**

```
 10  REM Seven-segment Count Up
 20  CLS
 30  DIM A(9)
 40  FOR X = 0 TO 9 : READ A(X) :
     NEXT X
 50  FOR Y = 0 TO 9
 60  OUT  512,A(Y)
 70  FOR Z = 0 TO 5000 : NEXT Z
 80  NEXT Y
 90  DATA 126, 12, 182, 158, 204, 218,
     250, 14, 254, 222
100  OUT  512,0
```

NOTE: This program goes through the numbers once, then turns off the display and ends.

3. Do number 2 above, but have the display count down.

**AppleSoft BASIC**

```
10  REM SEVEN-SEGMENT COUNT DOWN
20  TEXT : HOME
30  DIM A(9)
40  FOR X = 0 TO 9 : READ A(X) : NEXT X

50  FOR Y = 9 TO 0 STEP -1
60  POKE 49408,A(Y)
70  FOR Z = 0 TO 5000 : NEXT Z
80  NEXT Y
90  DATA 126, 12, 182, 158, 204, 218,
    250, 14, 254, 222
100 POKE 49408, 0
```

**BASICA or GW-BASIC**

```
10  REM Seven-segment Count Down
20  CLS
30  DIM A(9)
40  FOR X = 0 TO 9 : READ A(X) :
    NEXT X
50  FOR Y = 9 TO 0 STEP -1
60  OUT 512,A(Y)
70  FOR Z = 0 TO 5000 : NEXT Z
80  NEXT Y
90  DATA 126, 12, 182, 158, 204, 218,
    250, 14, 254, 222
100 OUT 512,0
```

NOTE: This program goes through the numbers once, then turns off the display and ends.

4. Use the display to display any number from 0 to 9 that is entered from the computer keyboard.

**AppleSoft BASIC**

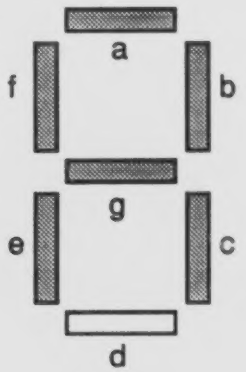
```
10  REM DISPLAY A NUMBER
20  DIM A(9)
30  FOR X = 0 TO 9 : READ A(X) : NEXT X

40  TEXT : HOME
50  INPUT "ENTER A NUMBER -> " ; N
60  IF N < 0 OR N > 9 THEN 90
70  POKE 49408, A(N)
80  GOTO 40
90  DATA 126, 12, 182, 158, 204, 218,
    250, 14, 254, 222
100 POKE 49408,0
```

**BASICA or GW-BASIC**

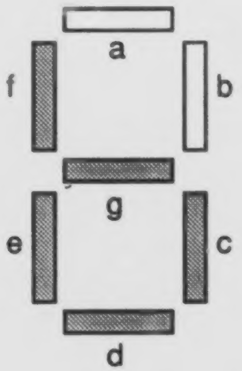
```
10  REM Display a Number
20  DIM A(9)
30  FOR X = 0 TO 9 : READ A(X) :
    NEXT X
40  CLS
50  INPUT "Enter a Number -> " ; N
60  IF N < 0 OR N > 9 THEN 90
70  OUT 512,A(N)
80  GOTO 40
90  DATA 126, 12, 182, 158, 204, 218,
    250, 14, 254, 222
100 OUT 512,0
```

NOTE: You must type the number, then press return. If a number greater than 9 or less than 0 is entered, the program turns off the display and ends.

5. Create a letter on the display (Hint: A and b are easy.)



238



248

# SEVEN-SEGMENT DISPLAY

*Build a seven-segment display, and operate it using the A-BUS relay card.*

## Objectives

- To demonstrate the application of seven-segment displays in digital and computer electronics
- To construct a working model of a seven-segment display
- To program the numbers from 0 to 9 on the display using an Apple or IBM computer

## Vocabulary/Concepts Reinforced

- Seven-segment display
- Reading schematic diagrams
- Wiring computer interfaces
- Programming computer interfaces
- Display decoder/driver
- Liquid crystal displays (LCDs)
- Light-emitting diodes (LEDs)

## Equipment/Supplies

- A-BUS Relay Card RE-140, cable, and A-BUS interface card for Apple II or IBM
- Seven 12V pilot lamps
- Seven fuse holders
- Seven small wood screws to mount fuse holders
- Soldering iron (see instructor for safety procedures)
- Screwdriver
- A supply of solid conductor wire
- A piece of thin plywood on which to mount the fuse holders

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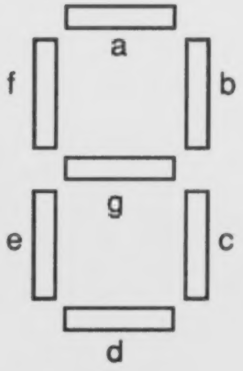
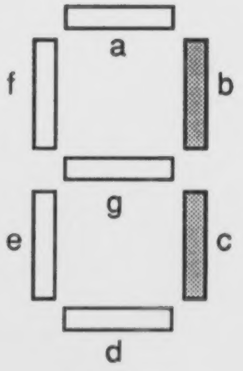
## Introduction

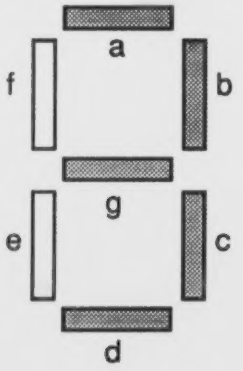
Seven-segment displays are used in digital watches, calculators, etc. Just as its name implies, the seven-segment display is made up of seven segments or sections arranged in the shape of an 8. Each segment is a bar that can be lit to display a line. When one or more of the segments are lit, they create a pattern that represents any number from 0 to 9 and some letters. Each segment is designated with a letter. A seven-segment display and some of the numbers possible are shown here:



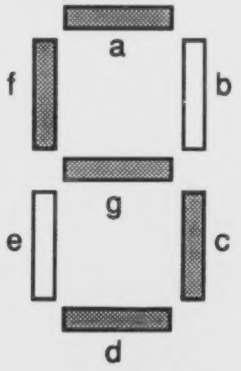
No segments lit



Display a 1
b + c



Display a 3
a + b + c + d + g

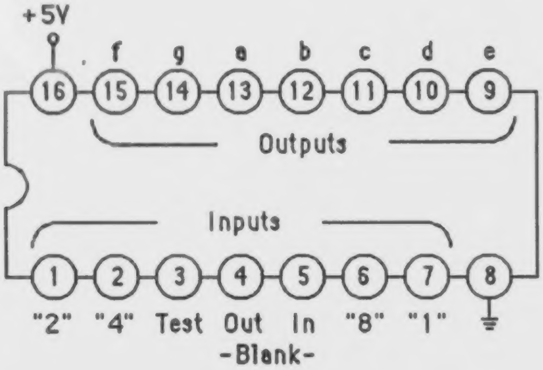


Display a 5
a + c + d + f + g

Seven-segment displays come in many sizes and types. Those used in digital watches are very small. Those on some football scoreboards are an example of the other extreme in size. The source of light in a seven-segment display may be small light-emitting diodes (LEDs), fluorescent tubes, or liquid crystal displays (LCDs). Most larger displays use incandescent bulbs as a source of light.

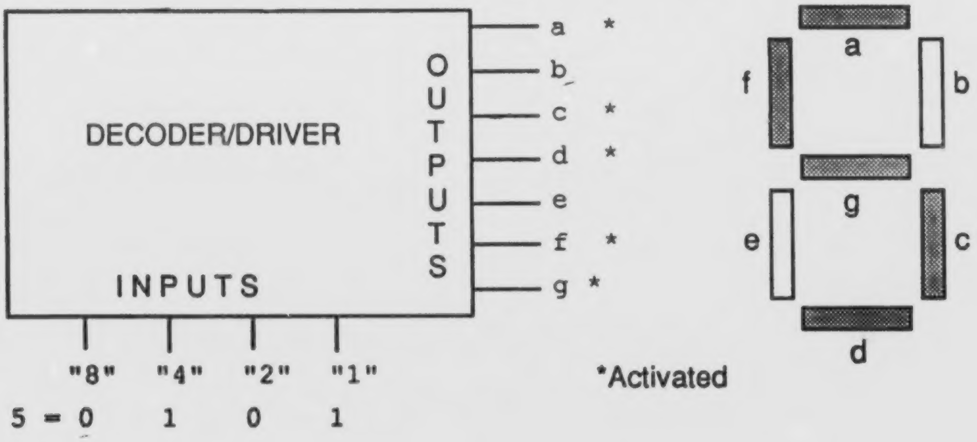
When used in a digital circuit, a seven-segment display must be connected to a source of power and a digital integrated circuit called a decoder/driver. Since digital circuits operate using binary numbers and logic, binary numbers must be "decoded" or translated to signals that will operate a seven-segment display properly. For example, the binary number 0101 must cause segments a, c, d, f, and g on the display to light. In addition, the display usually requires more power than most digital circuits can supply so that it must be connected to a "driver" which provides the necessary power.

An example of a display decoder/driver is shown below:



The inputs are indicated by the decimal equivalents of four binary digits: "1", "2", "4", and "8". The binary number up to 1001, or decimal 9, which is placed on these inputs causes the correct combination of outputs, lettered a to g, to become active. This action decodes the binary number and causes the seven-segment to display the proper number from 0 to 9.

*Example:* We want to display a 5. A 0101 is placed on the inputs of the decoder. Outputs a, c, d, f, and g become active. This creates a 5 on the display.



## Procedure

In this activity, you are going to construct a seven-segment display and use a computer to decode the numbers and a relay card to drive the display.

*Construction of the display:*

1. Cut out a piece of thin plywood to the size indicated in the drawing.
2. Mount the seven fuse holders on the board using the wood screws.
3. Wire and solder the display as shown in the schematic diagram. Insert pilot lamps.
4. Connect the completed display to the A-BUS relay card and a 12-volt battery.
5. Test the display by entering the appropriate test program into your computer and running it.

*Programming the display:*

- Each relay on the A-BUS card is activated by sending a number to the I/O port. When a relay is activated, it will close the circuit to the display and turn on one segment. The following list shows the number for each relay:

| Segment | Relay | Value |
|---|---|---|
| | 0 | 1 |
| a | 1 | 2 |
| b | 2 | 4 |
| c | 3 | 8 |
| d | 4 | 16 |
| e | 5 | 32 |
| f | 6 | 64 |
| g | 7 | 128 |

- By adding these numbers together, you can activate more than one relay at a time on the card. For example, sending a 6 to the I/O port will activate relay 1 and relay 2. This is how to get more than one segment to light at a time.
- The actual method of sending a number to the I/O port depends on the kind of computer you are using.

For Apple II computers in AppleSoft BASIC:

1. The slot holding the A-BUS interface card determines the "base address." These are:

| | |
|---|---|
| Slot 1 | 49408 |
| Slot 2 | 49664 |
| Slot 3 | 49920 |
| Slot 4 | 50176 |
| Slot 5 | 50432 |
| Slot 6 | 50688 |
| Slot 7 | 50944 |

2. A POKE statement is used to send the desired number to the A-BUS relay card. For example, if the interface card is in slot 1, a POKE 49408,6 will send a 6 to the A-BUS relay card, activate relays 1 and 2, and turn on segments a and b of the display.

3. Test program in AppleSoft BASIC with A-BUS interface card in slot 1. It will display an 8 for about 5 seconds, then turn all segments off.

```
10 TEXT : HOME
20 PRINT "TESTING SEVEN SEGMENT DISPLAY"
30 POKE 49408, 254
```

```
40  FOR Z = 0 TO 5000: NEXT Z
50  POKE  49408, 0
```

For IBM and compatible computers using BASICA or GW-BASIC:

1. The interface card in the IBM is set for a particular I/O port. The ports that work best in most IBMs and compatibles are 512 to 576.

2. Use an OUT statement to send the desired number to the A-BUS relay card. For example, if the base port is 512, the statement OUT 512, 6 will send a 6 to the A-BUS relay card, activate relays 1 and 2, and turn on segments a and b of the display.

3. Test program in IBM BASICA or GW-BASIC with A-BUS interface card set for port address 512. It will display an 8 for about 5 seconds (depends on speed of computer), then turn all segments off.

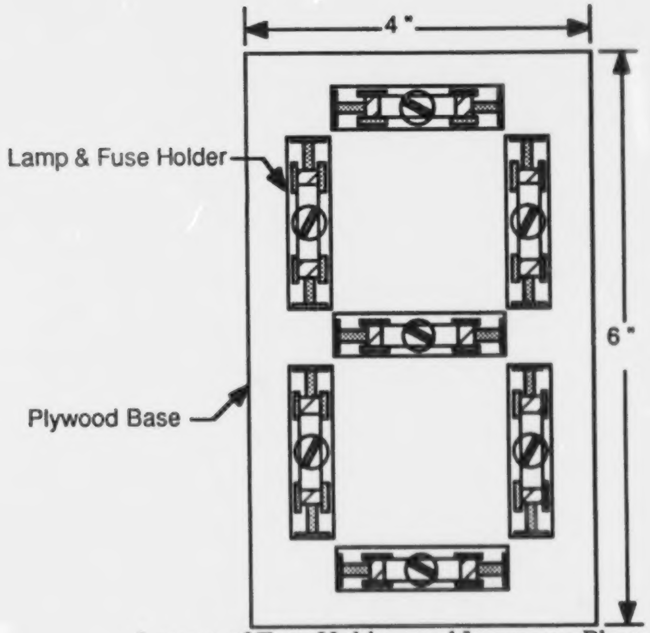
```
10  CLS
20  PRINT "Testing Seven Segment Display"
30  OUT  512, 254
40  FOR X = 0 TO 5000: NEXT
50  OUT  512, 0
```

## Evaluation

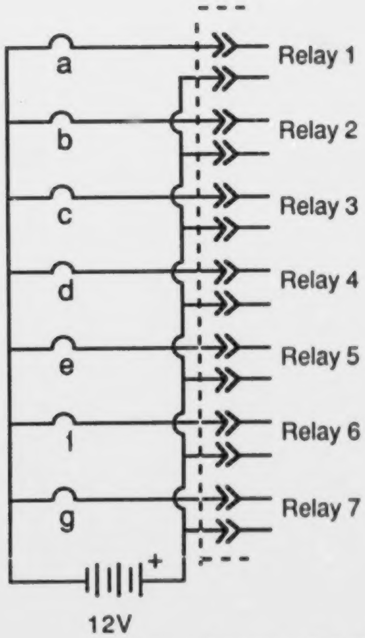
1. Write a program to create one of the numbers from 0 to 9 on the display.
2. Use the display to count up slowly from 0 to 9.
3. Do number 2 above, but have the display count down.
4. Use the display to display any number from 0 to 9 that is typed on the computer keyboard.
5. Create a letter on the display (Hint: **A** and **B** are easy.)

## Support Materials

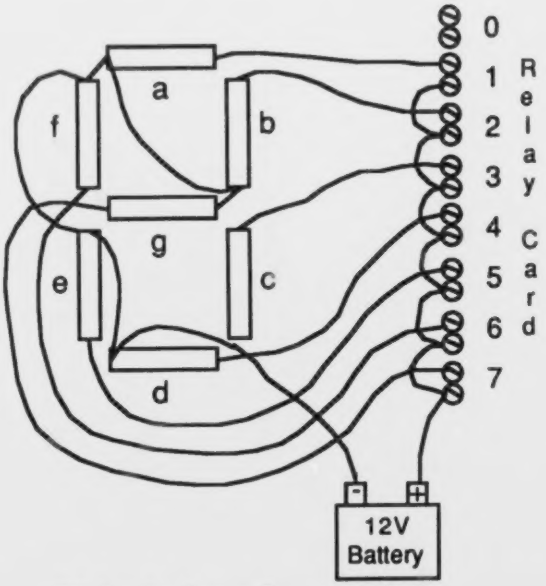
- The introduction to the A-BUS from this guide (Module 11)
- BASIC programming manual for Apple II or IBM


4"
6"
Lamp & Fuse Holder
Plywood Base

Layout of Fuse Holders and Lamps on Plywood


a
b
c
d
e
f
g
Relay 1
Relay 2
Relay 3
Relay 4
Relay 5
Relay 6
Relay 7
+
12V

Seven-Segment Display
Schematic Diagram


a
b
c
d
e
f
g
0
1
2
3
4
5
6
7
Relay Card
-
+
12V
Battery

Wiring the Seven-Segment Display

(2-3 DAYS)

# THERMISTORS AND TEMPERATURE

---

**Essential Elements:** Common: 8, 9
Specific: 1, 3, 9
**TAAS Objectives:** Mathematics: C 1-2; O 1-2; PS 2-3
Language Arts: RC 1-5

---

### Activity Summary

Students construct a temperature probe using a thermistor. The probe, when interfaced with the Apple II computer, illustrates the thermal properties of semiconductors.

### Teaching Tips

- Discuss the relationship between temperature and the resistance of materials in general. Then discuss the special case of semiconductors.
- Emphasize the relationship between the schematic drawing of the circuit and the completed circuit.
- Use a team approach to building and programming the temperature probe.
- To simplify the programming, have every student use the same slot in the Apple.
- Advanced students can be asked to calibrate the temperature probe more accurately and to demonstrate the nonlinear nature of a thermistor's response to temperature change.
- If the epoxy is applied correctly, the temperature probe can be used to measure the temperature of liquids.

### Instructional Strategy

This activity combines electrical/electronics construction skills, the mechanics of computer interfacing, and computer programming. Students are involved in all phases of the interfacing experience from the mechanics of wiring to programming. The activity lends itself to a team approach with some students doing the actual construction while others work primarily on the programming.

### Equipment/Supplies

- One 100 kΩ thermistor (NTC type)
- A supply of cable with two solid conductor wires
- A supply of shrink tubing and epoxy
- Soldering iron
- Hair dryer or similar heat source
- A thermometer capable of measuring 50°F to 120°F

### Evaluation Key

1. Write a program that can measure temperature using the thermistor temperature probe and print the temperature on the screen. *Note*: This program assumes that your thermistor is calibrated as the one on the student activity sheet. Substitute the appropriate values in line 40 to match your calibration.

**AppleSoft BASIC**

```
10 REM READ TEMPERATURE
20 TEXT : HOME
30 X = PDL (0)
40 T = ((X - 130) * .37)) + 70
```

```
50  VTAB 3 : CALL -868
60  PRINT "TEMPERATURE -> "T
70  GOTO 30
```

2. Write a program that will plot temperature values in the X axis on the HiRes graphics screen. *Note*: This program will plot the values as a moving horizontal line from left to right on the screen. When the plot reaches the right-hand side of the screen, the screen will be erased and the plot continue from the left. The program must be stopped with Ctrl-C.

**AppleSoft BASIC**

```
 10  REM PLOT TEMPERATURE
 20  HGR : HCOLOR = 3
 30  X = 1
 40  FOR Z = 0 TO 500 : NEXT Z
 50  Y = PDL (0)
 60  Y = 159 - (INT(159/255 * Y))
 70  HPLOT X,Y
 80  X = X + 1
 90  IF X > 279 THEN 20
100  GOTO 40
```

## THERMISTORS AND TEMPERATURE

*Use the Apple II game port and a thermistor temperature probe to measure temperature and illustrate the thermal properties of semiconductors.*

---

### Objectives

- To investigate the thermal properties of semiconductors
- To demonstrate interfacing of a thermistor to a microcomputer

### Vocabulary/Concepts Reinforced

- Semiconductor
- Thermistor
- Temperature coefficient
- Computer interfacing
- Analog to digital conversion

### Equipment/Supplies

- One 100 kΩ thermistor (NTC type)
- A supply of cable with two solid conductor wires
- A supply of shrink tubing and epoxy
- One DB9 male connector with solder lugs
- Soldering iron (see instructor for safety procedures)
- Hair dryer or similar heat source
- A thermometer capable of measuring 50°F to 120°F

---

### Introduction

The electrical resistance of every material changes with temperature. The relationship between resistance and temperature is called the *temperature coefficient* of the material. It is expressed in ohms per degree Celsius, or Ω/°C.

A temperature coefficient shows us two things about the material: (1) The value of the coefficient expresses the magnitude of resistance changes with temperature. (2) The sign of the coefficient determines the direction of the relationship. Some materials have small temperature coefficients and thus show little change in resistance when temperature changes (for example, constantan changes about 0.000008 Ω/°C). Other materials show large changes in resistance with temperature, so they have large temperature coefficient values (for example, iron changes about 0.0055 Ω/°C). Materials also vary in the direction of resistance changes with temperature. For example, the resistance of most metals increases as the temperature goes up. Thus, most metals are said to have a *positive* temperature coefficient (temperature higher—resistance higher). Other materials have a *negative* temperature coefficient (temperature higher—resistance lower). Most semiconductor materials have large negative temperature coefficients.

Thermistors are produced from specially manufactured semiconductor material that has a large and generally negative temperature coefficient. Thermistors are used widely as a sensor to measure temperature. They are simple to use but are limited to temperatures under about 100°C.

The voltage across a resistor will vary with the resistance. This fact is used to change the resistance of a thermistor into a voltage that can be input into a computer. Most computers cannot measure voltage directly, because they must have information in the form of digital numbers. When a computer is used to measure or record the voltage produced by a sensor, the values must be converted to digital numbers. This conversion can be done with an *analog to digital converter* (A to D converter).

The Apple II series computers have a gameport that can be used as an analog to digital converter. A variable resistance placed between one of the gamepaddle inputs and +5 volt output can be used to produce a digital number between 0 and 255 (8-bit converter). A simple program in AppleSoft BASIC can be used to record or measure the temperature of the thermistor.

### Procedure

*Measuring the resistance of a thermistor:*

1. Obtain a 100 kΩ NTC thermistor.
2. Use an ohmmeter to measure the resistance between the two leads.
3. Hold the thermistor between your fingers. As you warm the thermistor, you should see a decrease in resistance.

*Constructing the thermistor temperature probe:*

1. Cut a piece of two-conductor cable about 3 feet long, and strip the ends of the wires.
2. Carefully solder the thermistor leads to opposite sides of a 1/4" by 3" strip of two-sided PC board. Solder the wires to opposite sides of the circuit board. The wire colors are not important, but be sure that all the wires are insulated from each other.
3. Slip a 2-inch piece of shrink tubing over the wire, circuit board, and thermistor until the thermistor just sticks out.
4. Fill the end of the shrink tubing with epoxy so that the thermistor is sealed in the tubing.
5. Before the epoxy sets, shrink the tubing with a hair dryer.
6. Solder the other ends of the wires to two pins, and insert in positions 2 and 5 of the DB9 connector.

*Testing the temperature probe:*

1. Plug the DB9 connector into the external game port of the Apple, and test the probe by entering the program below into your computer and running it:

   **AppleSoft BASIC**

   ```
   10 REM TEMP TEST
   20 TEXT : HOME
   30 X = PDL (0)
   40 VTAB 3 : CALL -868
   50 PRINT “VALUE -> ”X
   60 GOTO 30
   ```

2. The program should display a number between 0 and 255. As you hold the thermistor end of the probe between your fingers, the value displayed on the screen should get smaller. This shows that the resistance of the thermistor is dropping.

*Calibrating the probe:*

1. Carefully tape the temperature probe and the thermometer together with masking tape so that the thermometer bulb and probe are close together but still exposed.
2. Use the program below:

**AppleSoft BASIC**

```
10  REM TEMP CALIBRATION
20  TEXT : HOME
30  X = PDL (0)
40  X = 255 - X
50  VTAB 3 : CALL -868
60  PRINT “VALUE -> ”X
70  GOTO 30
```

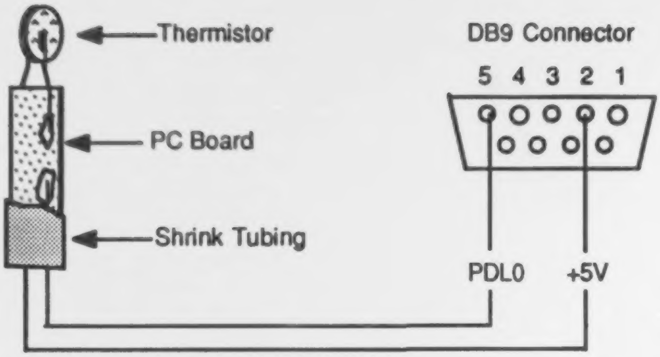
3. Run the program. A number between 0 and 255 should be displayed following the Value -> on the screen.
4. After the temperature probe has had time to stabilize (about 5 seconds), write down the current temperature on the thermometer and the value displayed on the screen. The number on the screen may seem to jump around, but just write down the value you see the most often. This will give you the first point for your calibration.
5. Use the hair dryer to heat up the temperature probe and the thermometer. Be careful not to heat them too quickly as the thermometer could be damaged.
6. When the temperature reaches about 100°F, record the temperature and value on the screen. This gives you the second temperature point for your calibration.
7. Determine the number of total decimal counts for your range of temperatures by subtracting the screen value at the low temperature from the screen value at the higher temperature.
8. Determine the temperature range by subtracting the lowest temperature from the higher temperature.
9. Find the number of degrees per count by dividing the temperature range from step 8 by the number of counts from step 7. This tells you how many degrees a count of one represents.

   For example:
   a. Your low temperature is 70°F and the screen value is 130.
   b. Your high temperature is 105°F and the screen value is 225.
   c. Decimal range = 225 - 130 = 95 counts
   d. Temperature range = 105°F - 70°F = 35°F
   e. Decimal count of one = 35°F / 95 = 0.37°F/count
10. This value can be used to determine the temperature at any displayed value. Using the example above, apply the following:

    Temp °F = (New Value on Screen - 130 x 0.37 ) + 70°F

**Evaluation**

1. Write a program that can measure temperature using the thermistor temperature probe and print the temperature on the screen.
2. Write a program that will plot temperature values in the X axis on the HiRes graphics screen.


Thermistor
PC Board
Shrink Tubing
DB9 Connector
5 4 3 2 1
PDL0
+5V

# COMPUTER-CONTROLLED TRAFFIC LIGHTS

**Essential Elements:** Common: 7, 9
Specific: 1, 2
**TAAS Objectives:** Mathematics: C 1, 2; O 1, 2; PS 2, 3
Language Arts: RC 1-5

## Activity Summary

Students will construct a pair of model traffic lights using pilot lamps, interface the models to a computer, and write programs to control an intersection. This activity combines electrical/electronics construction skills, the mechanics of computer interfacing, and computer programming. Students are involved in all phases of the interfacing experience from the mechanics of wiring to programming. The activity lends itself to a team approach with some students doing the actual construction while others work primarily on the programming. The finished product is also one that is a good "show-off" piece for the class and the teacher's program.

## Teaching Tips

1. Point out the role of traffic lights in controlling traffic.
2. Emphasize the need for coordination between the lights.
3. Demonstrate that traffic lights are programmed for different modes of operation at various time of the day depending on the volume of traffic.
4. Emphasize the relationship between the schematic drawing of the circuit and the final models.
5. To simplify the programming, have every student use the same slot in the Apple or port in the IBM. This will eliminate the problem of different base addresses.
6. The introduction to the A-BUS system in Module 11 and the A-BUS user's manuals are invaluable references for all activities using the system.

## Instructional Strategy

Use a team approach to building and programming the traffic lights.

## Equipment/Supplies

1. A-BUS Relay Card (RE-140), cable, and A-BUS interface card for Apple II or IBM
2. Six 12 V pilot lamps, Radio Shack No. 272-1137 (12V)
3. Six fuse holders, Radio Shack No. 270-739
4. Six small wood screws to mount fuse holders
5. Soldering iron and solder
6. Screwdriver
7. A supply of solid conductor wire
8. Two pieces of thin plywood on which to mount the fuse holders
9. Pieces of red, yellow, and green cellophane or transparent tape

## Evaluation Key

1. Go to a nearby intersection, and time the lights.

   Intersection timing varies from place to place depending on the traffic volume. Try to observe an intersection that has only a moderate amount of traffic. The experience can be expanded to include timing of intersections with turn arrows. If there are pedestrian walk signs, time them. Create a sequence chart for the intersection that shows all the activities of the lights.

2. Write a program that will operate the lights to control an intersection.

From the table below, assign the value of each traffic lamp to a variable. By adding the values of the variables together and then sending the result to the relay card, the proper combination of lights will be activated. Timing loops can be used to determine the length of each step in the sequence.

| Light | Relay | Value |
|---|---|---|
| | 0 | 1 |
| R1 | 1 | 2 |
| Y1 | 2 | 4 |
| G1 | 3 | 8 |
| R2 | 4 | 16 |
| Y2 | 5 | 32 |
| G2 | 6 | 64 |
| | 7 | 128 |

The following programs will cycle through the intersection control sequence three times, then shut all the lights off. Change the values of D1 and D2 in line 50 to control the speed. The AppleSoft BASIC program assumes that the interface card is in slot 1. The BASICA or GW-BASIC assumes that the interface card is set in the factory position (port 512).

**AppleSoft BASIC**

```
 10  REM TRAFFIC LIGHT OPERATION
 20  TEXT : HOME
 30  R1 = 2 : Y1 = 4 : G1 = 8
 40  R2 = 16 : Y2 = 32 : G2 = 64
 50  D1 = 1600 : D2 = 500
 60  FOR X = 1 TO 3
 70  POKE 49408,R1 + G2
 80  GOSUB 300
 90  POKE 49408,R1 + Y2
100  GOSUB 310
110  POKE 49108,G1 + R2
120  GOSUB 300
130  POKE 49408,Y1 + R2
140  GOSUB 310
150  NEXT X
160  POKE 49408,0
170  END
300  FOR Z = 0 TO D1 : NEXT Z : RETURN
310  FOR Z = 0 TO D2 : NEXT Z : RETURN
```

**BASICA or GW-BASIC**

```
 10  REM Traffic Light Operation
 20  CLS
 30  R1 = 2 : Y1 = 4 : G1 = 8
 40  R2 = 16 : Y2 = 32 : G2 = 64
 50  D1 = 1600 : D2 = 500
 60  FOR X = 1 TO 3
 70  OUT  512,R1 + G2
 80  GOSUB 300
 90  OUT  512,R1 + Y2
100  GOSUB 310
110  OUT  512,G1 + R2
120  GOSUB 300
130  OUT  512,Y1 + R2
140  GOSUB 310
150  NEXT X
160  OUT  512,0
170  END
300  FOR Z = 0 TO D1 : NEXT Z
     : RETURN
310  FOR Z = 0 TO D2 : NEXT Z
     : RETURN
```

3 Write a program that will switch the lights to flash one street yellow and the other red after a period of normal operation. Many intersections go into this mode of operation late at night.

The following programs will cycle through the intersection control sequence three times, then go into the late night routine—flashing Y1 and R2. After five cycles, all the lamps are turned off. Change the values of D1 and D2 in line 50 to control the speed. The AppleSoft BASIC program assumes that the interface card is in slot 1. The BASICA or GW-BASIC assumes that the interface card is set in the factory position (port 512).

**AppleSoft BASIC**

```
 10  REM TRAFFIC LIGHT LATE NIGHT
 20  TEXT : HOME
 30  R1 = 2 : Y1 = 4 : G1 = 8
 40  R2 = 16 : Y2 = 32 : G2 = 64
 50  D1 = 1600 : D2 = 500
 60  FOR X = 1 TO 3
 70  POKE 49408,R1 + G2
 80  GOSUB 300
 90  POKE 49408,R1 + Y2
100  GOSUB 310
110  POKE 49108,G1 + R2
120  GOSUB 300
130  POKE 49408,Y1 + R2
140  GOSUB 310
150  NEXT X
160  FOR X = 1 TO 5
170  POKE 49408, R1 + Y2
180  GOSUB 310
190  POKE 49408,0
200  GOSUB 310
210  NEXT X
220  END
300  FOR Z = 0 TO D1 : NEXT Z : RETURN
310  FOR Z = 0 TO D2 : NEXT Z : RETURN
```

**BASICA or GW-BASIC**

```
 10  REM Traffic Light Late Night
 20  CLS
 30  R1 = 2 : Y1 = 4 : G1 = 8
 40  R2 = 16 : Y2 = 32 : G2 = 64
 50  D1 = 1600 : D2 = 500
 60  FOR X = 1 TO 3
 70  OUT  512,R1 + G2
 80  GOSUB 300
 90  OUT  512,R1 + Y2
100  GOSUB 310
110  OUT  512,G1 + R2
120  GOSUB 300
130  OUT  512,Y1 + R2
140  GOSUB 310
150  NEXT X
160  FOR X = 1 TO 5
170  OUT  512, R1 + Y2
180  GOSUB 310
190  OUT  512,0
200  GOSUB 310
210  NEXT X
220  END
300  FOR Z = 0 TO D1 : NEXT Z
     : RETURN
310  FOR Z = 0 TO D2 : NEXT Z
     : RETURN
```

# COMPUTER-CONTROLLED TRAFFIC LIGHTS

*Build two traffic lights and operate using the A-BUS relay card.*

---

### Objectives

- To construct two computer-controlled traffic light models
- To program the traffic lights using an Apple or IBM computer

### Vocabulary/Concepts Reinforced

- Role of lights in traffic control
- Reading schematic diagrams
- Wiring computer interfaces
- Programming computer interfaces

### Equipment/Supplies

- A-BUS Relay Card (RE-140), cable, and A-BUS interface card for Apple II or IBM
- Six 12 V pilot lamps
- Six fuse holders
- Six small wood screws to mount fuse holders
- Soldering iron (see instructor for safety procedures)
- Screwdriver
- A supply of solid conductor wire
- Two pieces of thin plywood on which to mount the fuse holders
- Pieces of red, yellow, and green cellophane or transparent tape

---

### Introduction

Everyone is familiar with traffic lights, but have you really thought about what they do or how they work? Traffic lights control the flow of traffic through an intersection. Not counting turn arrows, each light contains three colored bulbs or lenses. All six of the lights for a two-street intersection must be operated in the proper sequence for them to do their job. Traffic on one street must be held by a red, while the cross street receives a green. Drivers must be warned that a red is coming up by a yellow, giving them time to slow down. All of this must be carefully coordinated to ensure a smooth, safe flow of traffic through an intersection. A failure of the lights can have unpleasant results—for example, if both streets are showing green lights.

Most traffic lights are controlled by timers, clocks, and relays mounted in a box on one of the poles supporting the lights. It is possible, however, to use a computer to control the lights. In fact, some cities are going to computer control since it allows the timing of the intersection to be changed as traffic changes during the day.

The sequence of the red, yellow, and green lights and their time of operation in a typical intersection are shown on the next page.

| Street 1 | Street 2 | Time |
|---|---|---|
| Red | Green | 27 sec. |
| Red | Yellow | 3 sec. |
| Green | Red | 27 sec. |
| Yellow | Red | 3 sec. |
| Red | Green | 27 sec. |

## Procedure

*Construction of the traffic lights:*

1. Cut out two pieces of thin plywood to the size indicated in the drawing.
2. Mount three fuse holders on each piece of board using the wood screws.
3. Wire and solder the fuse holders as shown in the schematic diagram.
4. Wrap the pilot lamps with transparent tape or colored cellophane to create the red, yellow, and green lamps. Plug them into the correct fuse holders.
5. Connect the completed lights to the A-BUS relay card and a 12-volt battery.
6. Test the lights by entering the appropriate test program into your computer and running it.

*Programming the lights:*

- Each relay on the A-BUS card is activated by sending a number to the I/O port. When a relay is activated, it will close the circuit to the display and turn on one light. The following list shows the number for each relay and traffic light:

| Light | Relay | Value |
|---|---|---|
|  | 0 | 1 |
| R1 | 1 | 2 |
| Y1 | 2 | 4 |
| G1 | 3 | 8 |
| R2 | 4 | 16 |
| Y2 | 5 | 32 |
| G2 | 6 | 64 |
|  | 7 | 128 |

- By adding these numbers together you can activate more than one relay at a time on the card. For example, sending a 66 to the I/O port will activate relay 1 and relay 6, which then will turn on lights R1 and G2. This is how to get more than one light on at a time.

- The actual method of sending a number to the I/O port depends on the kind of computer you are using.

For Apple II computers in AppleSoft BASIC:

1. The slot holding the A-BUS interface card determines the "base address." These are:

| | |
|---|---|
| Slot 1 | 49408 |
| Slot 2 | 49664 |
| Slot 3 | 49920 |
| Slot 4 | 50176 |
| Slot 5 | 50432 |
| Slot 6 | 50688 |
| Slot 7 | 50944 |

2. A POKE statement is used to send the desired number to the A-BUS relay card. For example, if the interface card is in slot 1, a POKE 49408,66 will send a 66 to the A-BUS relay card, activate relays 1 and 6, and turn on lights R1 and G2.

3. This test program in Applesoft BASIC with A-BUS interface card in slot 1 turns on all the traffic lights for about 5 seconds, then turns them off.

```
10 TEXT : HOME
20 PRINT "TESTING TRAFFIC LIGHTS"
30 POKE  49408, 126
40 FOR X = 0 TO 5000: NEXT
50 POKE  49408, 0
```

For IBM and compatible computers using BASICA or GW-BASIC:

1. The interface card in the IBM is set for a particular I/O port. The ports that work best in most IBMs and compatibles are 512 to 576.

2. Use an OUT statement to send the desired number to the A-BUS relay card. For example, if the base port is 512, the statement OUT 512,66 will send a 66 to the A-BUS relay card, activate relays 1 and 6, and turn on lights R1 and G2.

3. Test program in IBM BASICA or GW-BASIC with A-BUS interface card set for port address 512. It will turn on all the traffic lights for about 5 seconds, then turn them off.

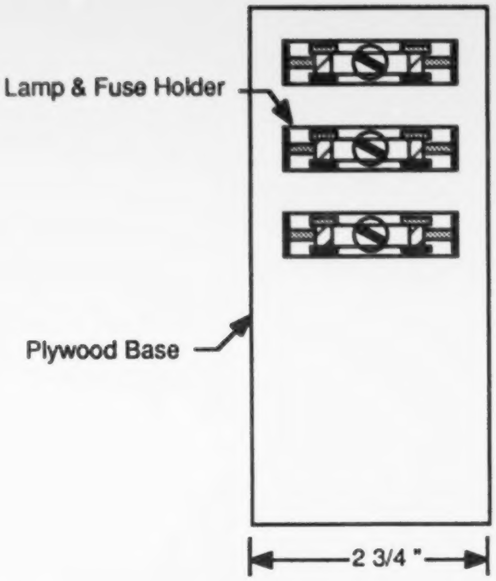
```
10 CLS
20 PRINT "Testing Traffic Lights"
30 OUT  512,126
40 FOR X = 0 TO 5000: NEXT
50 OUT  512, 0
```

### Evaluation

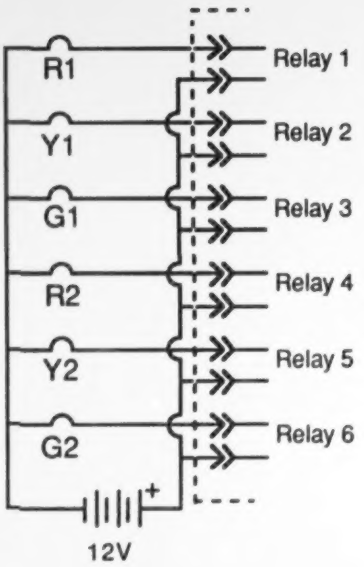
1. Go to a nearby intersection, and time the lights. Make up a chart that shows the sequence of the intersection you timed.
2. Write a program that will operate the lights to control the intersection.
3. Write a program that will switch the lights to flash one street yellow and the other red after a period of normal operation. Many intersections go into this mode of operation late at night.

### Support Materials

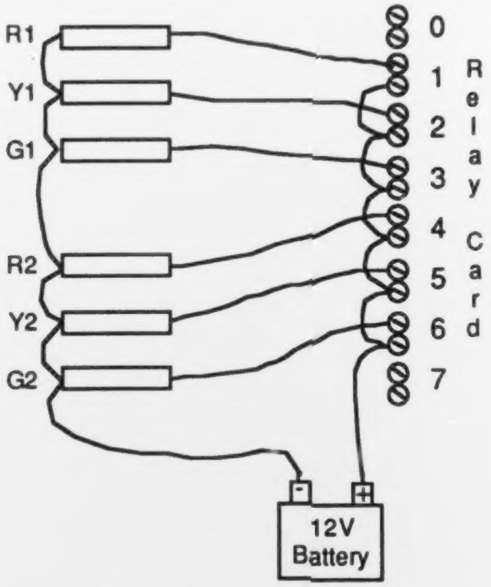
- The introduction to the A-BUS from this guide (Module 11)
- BASIC programming manual for Apple II or IBM


Lamp & Fuse Holder
Plywood Base
6 "
2 3/4 "

One Traffic Light
Layout of Fuse Holders and Lamps on Plywood


R1
Y1
G1
R2
Y2
G2
Relay 1
Relay 2
Relay 3
Relay 4
Relay 5
Relay 6
+
12V

Traffic Lights
Schematic Diagram


R1
Y1
G1
R2
Y2
G2
0
1
2
3
4
5
6
7
Relay Card
-
+
12V Battery

Wiring the Traffic Lights

(1 WEEK)

# ELECTRONIC ETCH-A-SKETCH

---

**Essential Elements:** Common: 8-10
Specific: 1, 11
**TAAS Objectives:** Mathematics: C 1, 2; O 1, 2; PS 2, 3
Language Arts: RC 1-5

---

## Activity Summary

Students construct an electronic Etch-A-Sketch using two potentiometers and the A-BUS A-D interface card. Students then write simple programs in BASIC that allow them to draw on the computer screen. This activity combines electrical/electronics construction skills, the mechanics of computer interfacing, and computer programming. Students are involved in all phases of the interfacing experience from the mechanics of wiring to programming. The activity lends itself to a team approach with some students doing the actual construction while others work primarily on the programming.

## Teaching Tips

1. Emphasize the relationship between the schematic drawing of the circuit and the completed circuit.
2. To simplify the programming, have every student use the same slot in the Apple or port in the IBM. This will eliminate the problem of different base addresses.
3. The introduction to the A-BUS system (Module 11) and the A-BUS user's manuals are invaluable references for all activities using the system.
4. The potentiometers used can have values of 10 kΩ to 50 kΩ. They must be linear or alpha type potentiometers. Do not use an audio (nonlinear) potentiometer.
5. If the lines drawn on the graphics screen do not go in the right direction, reverse the +5 and GND connections at the A-D card.
6. For the smoothest and most reliable operation, move the jumper at J6 to C for continuous conversion.

## Instructional Strategy

Use a team approach to building and programming the Etch-A-Sketch.

## Equipment/Supplies

1. A-BUS Analog Input Card (AD-142), cable, and A-BUS interface card for Apple II or IBM
2. Two 50 kΩ potentiometers (Radio Shack Cat. No. 271-1716)
3. Knobs for the potentiometers
4. Soldering iron and solder
5. A supply of solid conductor wire
6. A piece of plastic or thin plywood on which to mount the potentiometers

## Evaluation Key

1. Write a program that will draw in white on both the horizontal vertical axes of the HiRes screen. Press Cntrl-C or Cntrl-Break to end the program.

**AppleSoft BASIC**

```
 10 REM DRAW IN WHITE
 20 HGR : HCOLOR = 3
 30 POKE 49408,0
 40 X = PEEK (49408)
 50 X = INT (X * (279/255))
 60 POKE 49408,1
 70 Y = PEEK (49408)
 80 Y = INT (Y * (159/255))
 90 HPLOT X,Y
100 GOTO 30
```

**BASICA or GW-BASIC**

```
 10 REM Draw in White
 20 SCREEN 1
 30 CLS
 40 OUT 512,0
 50 X = INP (512)
 60 OUT 512,1
 70 Y = INP (512)
 80 IF Y > 184 THEN Y = 184
 90 PSET (X,Y)
100 GOTO 40
```

2. Write a program that will draw black lines on a white screen, like a real Etch-A-Sketch. Press Cntrl-C or Cntrl-Break to end the program.

**AppleSoft BASIC**

```
 10 REM ELECTRONIC ETCH-A-SKETCH
 20 HGR : HCOLOR = 3
 30 HPLOT 0,0 : CALL 62454
 40 HCOLOR = 0
 50 POKE 49408,0
 60 X = PEEK (49408)
 70 X = INT (X * (279/255))
 80 POKE 49408,1
 90 Y = PEEK (49408)
100 Y = INT (Y * (159/255))
110 HPLOT X,Y
120 GOTO 50
```

**BASICA or GW-BASIC**

```
 10 REM Electronic Etch-A-Sketch
 20 SCREEN 1
 30 CLS
 40 COLOR 0
 50 FOR X = 31 TO 287 : PSET (X,0) : PSET (X,186) : NEXT
 60 FOR Y = 0 TO 184 : PSET (31,Y) : PSET (288,Y) : NEXT
 70 PAINT (144,92)
 80 OUT 512,0
 90 X = INP (512) + 32
100 OUT 512,1
110 Y = INP (512) + 1
120 IF Y > 184 THEN Y = 184
130 PSET (X,Y),0
140 GOTO 80
```

# ELECTRONIC ETCH-A-SKETCH

*Build an electronic Etch-A-Sketch using the A-BUS A-D card, and draw on the computer screen.*

---

## Objectives

- To understand the operation of an analog to digital converter
- To properly wire and solder the electronic components used in the Etch-A-Sketch
- To write a working program in BASIC that uses the A-D converter and plots on the computer screen
- To create images using the computer

## Vocabulary/Concepts Reinforced

- Applications of analog to digital converters
- HiRes graphics programming

## Equipment/Supplies

- A-BUS Analog Input Card (AD-142), cable, and A-BUS interface card for Apple II or IBM
- Two 50 kΩ potentiometers
- Knobs for the potentiometers
- Soldering iron (see instructor for safety procedures)
- A supply of solid conductor wire
- A piece of plastic or thin plywood on which to mount the potentiometers

---

## Introduction

This activity combines the A-BUS A-D card and two potentiometers to create an electronic Etch-A-Sketch. The Etch-A-Sketch is then used to draw on the computer's graphics screen. Operation of this electronic sketching device is based on a computer interface known as *analog to digital conversion.* The two potentiometers are used to create two varying voltages which are then converted into numbers by the analog to digital card. These numbers are then used to plot on the computer's HiRes graphics screen.

In science, medicine, and industry, computers are often used for the measurement and storage of information about physical variables such as pressure, temperature, volume, weight, position, brightness, and flow rate. These physical variables are also called *analog variables.*

Analog variables can have any number of values between two extremes. Position is an example. When an object is positioned along a line, it will be in one of an unlimited number of possible positions. No matter where the object is, we can always move it to a new position just a little different from the last. This same idea applies to most of the other physical variables such as pressure, temperature, or brightness. *Sensors* are used to measure the value of analog variables. Most sensors convert physical variables, such as pressure or temperature, to a voltage or current.

Most computers cannot use an analog signal like voltage or current directly. The computer must have information in the form of digital numbers. When a computer is used to measure or record the voltage or current produced by a sensor, the values must be converted to digital numbers. This conversion can be done with an *analog to digital converter* (A to D converter). Depending on the converter, the number produced may have from four to as many as twenty binary bits or digits. For example, a four bit converter will produce decimal numbers from 0 to 16 ($2^4$). A to D converters vary in the type and range of input they can convert. Some convert voltage while others are designed to convert current. Converters also operate with different ranges of voltage or current input.

A *potentiometer* (variable resistor) can be used as a sensor to measure position or rotation. Potentiometers are used on some lathes to determine the position of the tool. They are also used to measure the movement of the tail surfaces of airplanes. This is done by wiring the potentiometer so that a varying voltage is created when its shaft is rotated. If the potentiometer is connected to an A to D converter, this voltage can be input to a computer as a binary or decimal number. The computer can then be used to record or measure the position of the potentiometer's shaft.

## Procedure

*Constructing the Etch-A-Sketch:*

1. Cut out a piece of plastic/plywood to a size appropriate for the two potentiometers. Lay out and label the panel for vertical and horizontal movements as in the wiring diagram.
2. Drill two 1/2" holes in which to mount the potentiometers.
3. Mount the potentiometers.
4. Attach the knobs onto the potentiometers.
5. Wire and solder the potentiometers as shown in the schematic diagram.
6. Connect the potentiometers to the A-BUS analog input card using channels 0 and 1.
7. Test the system by entering the appropriate test program into your computer and running it.

*Programming the A to D converter:*

- The A-BUS analog to digital card used in this activity converts voltages ranging from 0 to 5.1 volts to an 8-bit binary number. The number will be prportional to the voltage applied. When programming in BASIC, this binary number is converted to a decimal number. As the voltage ranges from 0 to 5.1 volts, the decimal number created by the converter will range from 0 to 255. Each step from 0 to 255 represents a change of 20 mV (0.02 volt) or 5.1 volts/255.
- The A-BUS A-D card can have up to eight analog voltage sources (or channels) connected to it at one time. To read one of the eight channels, you first select the channel and then read the result of the conversion. This is done by sending the number of the channel to the input/output (I/O) port, then reading the value of the conversion through the I/O port.
- The actual method of doing an analog to digital conversion depends on the kind of computer you are using.

For Apple II computers in AppleSoft BASIC:

1. The slot holding the A-BUS interface card determines the "base address." These are:

| | |
|---|---|
| Slot 1 | 49408 |
| Slot 2 | 49664 |
| Slot 3 | 49920 |
| Slot 4 | 50176 |
| Slot 5 | 50432 |
| Slot 6 | 50688 |
| Slot 7 | 50944 |

2. A POKE statement is used to send the desired channel number to the A-BUS A to D card. For example, with the interface card in slot 1, a POKE 49408,1 will send a 1 to the A-BUS A to D card and cause channel 1 to make a conversion.

3. A PEEK statement is then used to read the converted value and assign it to a variable. The following program illustrates this sequence.

```
10 POKE 49408,1
20 X = PEEK (49408)
30 PRINT X
```

For IBM and compatible computers using BASICA or GW-BASIC:

1. The interface card in the IBM is set for a particular I/O port. The ports that work best in most IBMs and compatibles are 512 to 576.

2. Use an OUT statement to send the desired channel number to the A-BUS A to D card. For example, if the base port is 512, the statement OUT 512,1 will send a 1 to the A-BUS card and cause channel 1 to make a conversion.

3. An INP statement is then used to read the converted value and assign it to a variable. The following program illustrates this sequence.

```
10 OUT  512,1
20 X = INP(512)
30 PRINT X
```

Plotting on the HiRes graphics screens:

- The Apple II and IBM PC differ considerably in their graphics capabilities. Both, however, can be programmed in BASIC to plot individual pixels (dots) on the screen. The best source for information on how these computers are programmed for graphics is the BASIC language reference manuals for each computer.

Test Programs

1. Connect the completed Etch-A-Sketch that you constructed to channel 1 of the A-BUS A to D card as illustrated in the drawing. This circuit is powered by the A-BUS card and, when the potentiometers are turned, will produce varying voltages at channels 0 and 1.

2a. The following is a test program for AppleSoft BASIC with the A-BUS adapter in slot 1. This program will convert the voltage at channel 0 and draw a horizontal line on the HiRes screen. As you turn the potentiometer, you will see a line appear. Press Cntrl-C to end the program.

```
10 REM HORIZONTAL LINE
20 HGR : HCOLOR = 3
```

```
30 POKE  49408, 0
40 X = PEEK (49408)
50 HPLOT X,70
60 GOTO 30
```

2b. The following is a test program for IBM BASICA or GW-BASIC with the A-BUS adapter set for port 512. This program will convert the voltage at channel 0 and draw a horizontal line on the HiRes screen. As you turn the potentiometer, you will see a line appear. Press Cntrl-Break to end the program.

```
10 REM Horizontal Line
20 SCREEN 1
30 CLS
40 COLOR 0
50 OUT  512,0
60 X = INP (512)
70 PSET (X,90)
80 GOTO 50
```

## Evaluation

1. Write a program that will draw in white on both the horizontal and vertical axes of the HiRes screen.
2. Write a program that will draw black lines on a white screen, like a real Etch-A-Sketch.

*Hints*

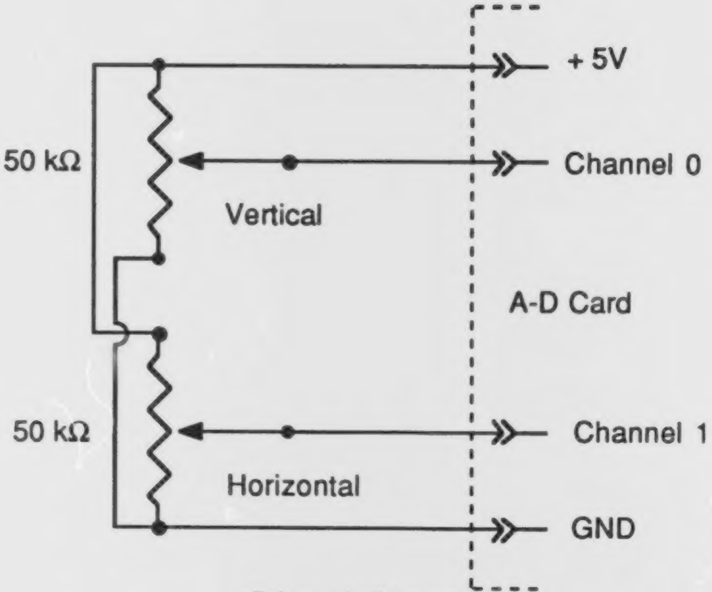
- For AppleSoft BASIC, the following sequence of commands will clear the screen quickly to white: HCOLOR = 3 : HPLOT 0,0 : CALL 62454 : HCOLOR = 0

- For BASICA/GW-BASIC, the following sequence of commands will draw a box on screen 1 and paint it white:

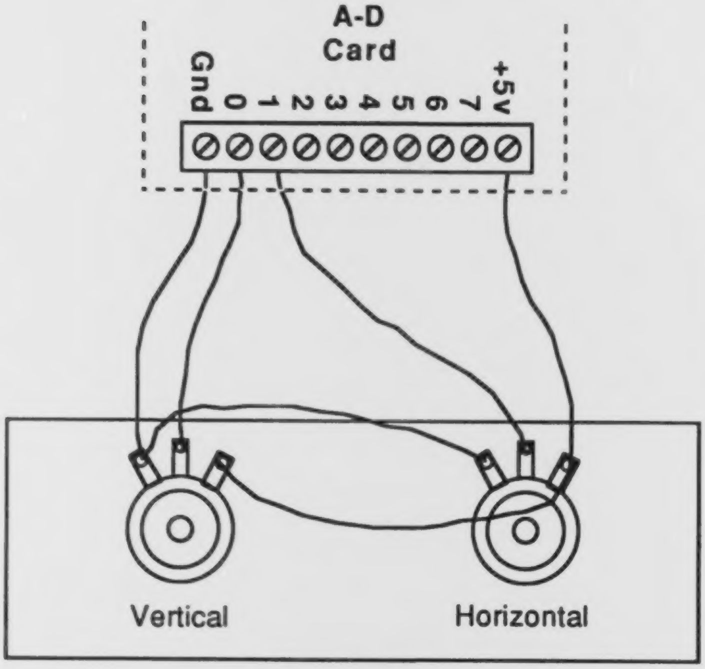
```
SCREEN 1 : CLS : COLOR 0
FOR X = 31 TO 287 : PSET (X,0) : PSET (X,186) : NEXT
FOR Y = 0 TO 184 : PSET (31,Y) : PSET (288,Y) : NEXT
PAINT (144,92)
```

## Support Materials

- The introduction to the A-BUS from this guide (Module 11)
- BASIC programming manual for Apple II or IBM


+ 5V
50 kΩ
Channel 0
Vertical
A-D Card
50 kΩ
Channel 1
Horizontal
GND

Schematic Diagram


A-D
Card
Gnd
0
1
2
3
4
5
6
7
+5v
Vertical
Horizontal

Wiring Diagram

# LIGHT-INTENSITY SENSOR

---

**Essential Elements:** Common: 8, 9
Specific: 1
**TAAS Objectives:** Mathematics: C 1, 2; O 1, 2; PS 2, 3
Language Arts: RC 1-5

---

### Activity Summary

Students measure the relative intensity of light sources using a CsD photoresistive cell and the A-BUS A-D interface card. This activity combines electrical/electronics construction skills, the mechanics of computer interfacing, and computer programming. Students are involved in all phases of the interfacing experience from the mechanics of wiring to programming. The activity lends itself to a team approach with some students doing the actual construction while others work primarily on the programming.

### Teaching Tips

1. Emphasize the relationship between the schematic drawing of the circuit and the completed circuit.
2. To simplify the programming, have every student use the same slot in the Apple or port in the IBM. This will eliminate the problem of different base addresses.
3. The introduction to the A-BUS system (Module 11) and the A-BUS user's manuals are invaluable references for all activities using the system.
4. CsD photoresistors vary in their resistance range. Most will have about 10-200Ω in darkness and about 250-3000Ω in high illumination. To be sure about your photoresistor, measure it with an ohmmeter. The CsD cells used as the basis for this activity came from Radio Shack and had about 170Ω in the dark and about 3000Ω when illuminated by room light.
5. If the values displayed on the screen do not go in the right direction (e.g., increase in value with an increase in illumination), reverse the +5 and GND connections at the A-D card.
6. For the smoothest and most reliable operation, move the jumper at J6 to C for continuous conversion.
7. The CsD cell will respond relatively fast to changes in lighting. This makes it a bit more exciting than the temperature probe.

### Instructional Strategy

Use a team approach to building and programming the light-intensity sensor.

### Equipment/Supplies

1. A-BUS 8-Channel Analog Input Card (AD-142), cable, and A-BUS interface card for Apple II or IBM
2. One cadmium sulfide (CsD) photoresistive cell:
   Radio Shack Cat. No. 276-1657
   Mouser Electronics Cat. No. 524-611-J4-805
3. A supply of cable with three conductor wires
4. Soldering iron and solder
5. A supply of shrink tubing
6. Hair dryer or similar heat source

**Evaluation Key**

The AppleSoft BASIC version of the programs below assumes that the A-BUS interface card is in slot 1, while the IBM BASICA or GW-BASIC versions assume that the interface card is set in the factory position (port 512).

1. Write a program that will display the light values from the A-D card. Press Cntrl-C or Cntrl-Break to stop the program.

**AppleSoft BASIC**

```
10 REM LIGHT-INTENSITY
20 TEXT : HOME
30 POKE 49408,1
40 FOR Z = 0 TO 500 : NEXT Z
50 X = PEEK (49408)
60 VTAB 3 : CALL -868
70 PRINT "LIGHT VALUE - > "X
80 GOTO 30
```

**BASICA or GW-BASIC**

```
10 REM Light-intensity
20 CLS
30 OUT 512,1
40 FOR Z = 0 TO 500 : NEXT Z
50 X = INP (512)
60 LOCATE 3,1 : PRINT "Light Value -> "
70 LOCATE 3,16 : PRINT X
80 GOTO 30
```

2. Write a program that will plot the light values in the X axis on the HiRes graphics screen. This program will plot the values as a moving horizontal line from left to right on the screen. When the plot reaches the right-hand side of the screen, the screen will be erased and the plot will continue from the left. The program must be stopped with Cntrl-C or Cntrl-Break.

**AppleSoft BASIC**

```
10 REM PLOT LIGHT-INTENSITY
20 HGR : HCOLOR = 3
30 X = 1
40 POKE 49408,1
50 FOR Z = 0 TO 50 : NEXT Z
60 Y = PEEK (49408)
70 Y = 159 - (INT(159/255 * Y))
80 HPLOT (X,Y)
90 X = X + 1
100 IF X > 279 THEN 20
110 GOTO 40
```

**BASICA or GW-BASIC**

```
10 REM Plot Light-intensity
20 SCREEN 1 : CLS
30 X = 1
40 OUT 512,1
50 FOR Z = 0 TO 50 : NEXT Z
60 Y = INP(512)
70 Y = 200 - (INT(200/255 * Y))
80 PSET (X,Y)
90 X = X + 1
100 IF X > 320 THEN 20
110 GOTO 40
```

## LIGHT-INTENSITY SENSOR

*Use an analog to digital converter and photoresistor to measure light level.*

---

### Objectives

- To understand the operation of an analog to digital converter
- To properly wire and solder the electronic components
- To write a working program in BASIC that uses the A-D converter and photoresistor to measure light level

### Vocabulary/Concepts Reinforced

- Applications of analog to digital converters.
- Cadmium sulfide photoresistive cell
- Analog variables
- Digital
- Sensors
- Photoresistors

### Equipment/Supplies

- A-BUS 8-Channel Analog Input Card (AD-142), cable, and A-BUS interface card for Apple II or IBM
- One cadmium sulfide (CsD) photoresistive cell
- A supply of cable with three solid conductor wires
- Soldering iron (see instructor for safety procedures)
- A supply of shrink tubing
- Hair dryer or similar heat source

---

### Introduction

In science, medicine, and industry, computers are often used for the measurement and storage of information about physical variables such as pressure, temperature, volume, weight, position, brightness, and flow rate. These physical variables are also called *analog variables*.

Analog variables can have any number of values between two extremes. The intensity of light shining on a surface is an example. Any given level of brightness is only one of an unlimited number of possible levels. No matter how bright or dim the lighting is, it can always be changed to be just a little different. This same idea applies to most of the other physical variables such as pressure, position, or temperature. *Sensors* are used to measure the value of analog variables. Most sensors convert physical variables, such as pressure or temperature, to a voltage or current.

Most computers cannot use an analog signal like voltage or current directly. The computer must have information in the form of digital numbers. When a computer is used to measure or record the voltage or current produced by a sensor, the values must be converted to digital numbers. This conversion can be done with an *analog to digital converter* (A to D converter). Depending on the converter, the number produced may have from four to as many as twenty binary bits or digits. For example, a 4-bit converter will produce decimal numbers from 0 to 16 ($2^4$). A to D converters vary in the type and range of input they can convert. Some convert voltage while others are designed to convert current. Converters also operate with different ranges of voltage or current input.

A *photoresistor* can be used as a sensor to measure the brightness or intensity of light. Photoresistive sensors are commonly used to measure the brightness of light in a camera so that the proper exposure can be set. One type of photoresistor is the cadmium sulfide (CsD) cell. The CsD photo cell will vary in its resistance when it is exposed to different intensities of light. As the brightness of the light increases the resistance of the CsD cell will decrease. The CsD cell can be wired in series with a fixed resistor to create a voltage divider whose voltage will vary with the brightness of light shining on the cell. If this circuit is connected to an A to D converter, this voltage can be input to the computer as a binary or decimal number. The computer can then be used to record or measure the intensity of light falling on the CsD cell.

## Procedure

*Constructing the light-intensity sensor:*

1. Cut a piece of three-conductor cable about 3 feet long, and strip the ends of the wires.
2. Carefully solder the wires, CsD photoresistor, and 470Ω resistor as shown in the diagram. Make sure that all the wires are insulated from each other.
3. Insulate all connections with several pieces of shrink tubing.
4. Shrink the tubing with a hair dryer.
5. Connect the light-intensity sensor to the A-BUS analog input card as shown in the wiring diagram.
6. Test the sensor by entering the appropriate test program into your computer and running it.

*Programming the A to D converter:*

- The A-BUS analog to digital card used in this activity converts voltages ranging from 0 to 5.1 volts to an 8-bit binary number. The number will be proportional to the voltage applied. When programming in BASIC, this binary number is converted to a decimal number. As the voltage ranges from 0 to 5.1 volts, the decimal number created by the converter will range from 0 to 255. Each step from 0 to 255 represents a change of 20 mV (0.02 volt) or 5.1 volts/255.
- The A-BUS A-D card can have up to eight analog voltage sources (or channels) connected to it at one time. To read one of the eight channels, you first select the channel and then read the result of the conversion. This is done by sending the number of the channel to the input/output (I/O) port, then reading the value of the conversion through the I/O port.
- The actual method of doing an analog to digital conversion depends on the kind of computer you are using.

For Apple II computers in AppleSoft BASIC:

1. The slot holding the A-BUS interface card determines the "base address." These are:

| | |
|---|---|
| Slot 1 | 49408 |
| Slot 2 | 49664 |
| Slot 3 | 49920 |
| Slot 4 | 50176 |
| Slot 5 | 50432 |
| Slot 6 | 50688 |

Slot 7    50944

2. A POKE statement is used to send the desired channel number to the A-BUS A to D card. For example, with the interface card in slot 1, a POKE 49408,1 will send a 1 to the A-BUS card and cause channel 1 to make a conversion.

3. A PEEK statement is then used to read the converted value and assign it to a variable. The following program illustrates this sequence.

```
10  POKE 49408,1
20  X = PEEK (49408)
30  PRINT X
```

For IBM and compatible computers using BASICA or GW-BASIC:

1. The interface card in the IBM is set for a particular I/O port. The ports that work best in most IBMs and compatibles are 512 to 576.

2. Use an OUT statement to send the desired channel number to the A-BUS A-D card. For example, if the base port is 512, the statement OUT 512,1 will send a 1 to the A-BUS card and cause channel 1 to make a conversion.

3. An INP statement is then used to read the converted value and assign it to a variable. The following program illustrates this sequence.

```
10  OUT  512,1
20  X = INP(512)
30  PRINT X
```

Plotting on the HiRes graphics screens:

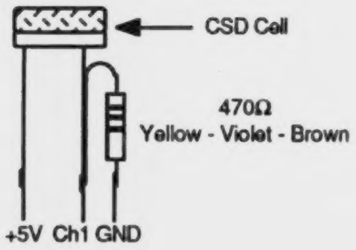
The Apple II and IBM PC differ considerably in their graphics capabilities. Both, however, can be programmed in BASIC to plot individual pixels (dots) on the screen. The best source for information on how these computers are programmed for graphics is the BASIC language reference manuals for each computer.

### Evaluation

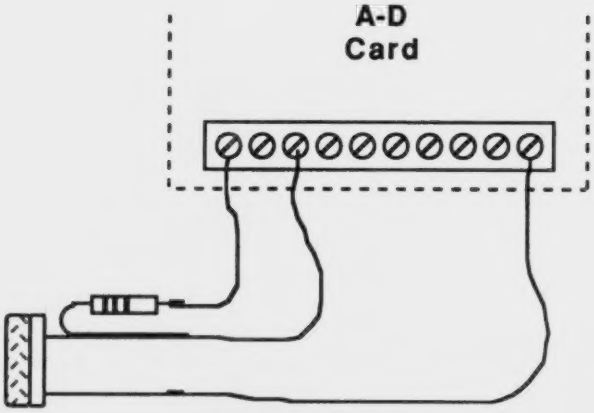
1. Write a program that will display the light values from the A-D card.
2. Write a program that will plot the light values in the X axis on the HiRes graphics screen.

### Support Materials

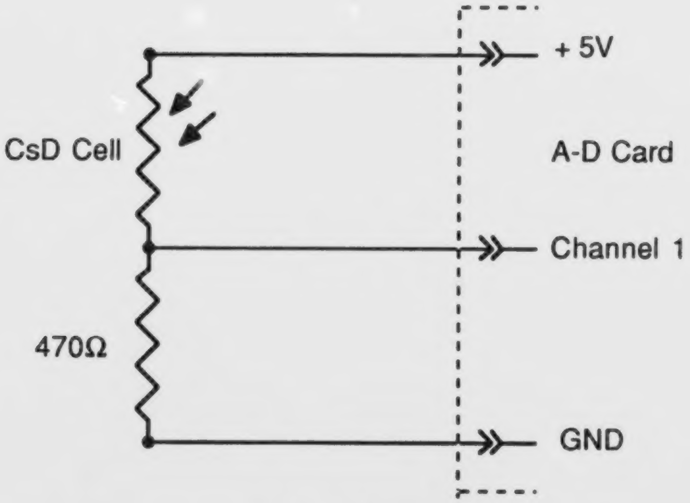
- The introduction to the A-BUS from this guide (Module 11)
- BASIC programming manual for Apple II or IBM


CSD Cell
470Ω
Yellow - Violet - Brown
+5V
Ch1
GND

Light-Intensity Sensor



Wiring Diagram


+ 5V
CsD Cell
A-D Card
Channel 1
470Ω
GND

Schematic Diagram

# PROGRAMMABLE LOGIC CONTROLLERS

---

**Essential Elements:** Common: 8, 9
Specific: 1
**TAAS Objectives:** Mathematics: C 1, 2; O 1, 2; PS 2, 3
Language Arts: RC 1-5

---

## Activity Summary

Students learn to write ladder logic programs on a programmable logic controller (PLC). This activity is on the outer reaches of computer applications. Programmable controllers have been an ignored topic for several years now. They are, however, becoming increasingly important in industry. This activity is intended as enrichment for advanced students or for the teacher who emphasizes the industrial applications of computers.

## Teaching Tips

1. Programmable controllers have wide industrial uses in many types of automatic computer controlled equipment. They are relatively new and have been a neglected topic. Programming them is, like CNC, not a trivia undertaking. You will need to study their applications and programming to some degree.
2. There are several manufacturers of programmable logic controllers. They include Allen-Bradley, Texas Instruments, General Electric, and OMRON. Each of these companies produces a wide variety of PLCs. Each varies in its installation and programming method. This activity concentrates on the OMRON model C-20 programmable controller. This is a relatively small and inexpensive controller, about $500.
3. The programmable controller I/O board does not use all of the capability of the OMRON C-20, but does allow simple experiments to be done.
4. There are many other devices besides lights that can be controlled with a PLC. Solenoids, relays, and motors are common output devices.
5. The manuals that come with the controller are the best learning resources for these machines.
6. It is not too difficult to come up with your own assignments for the PLC. Just make sure that you can make the program work before you assign it.

## Instructional Strategy

- Emphasize the relationship between the schematic drawing of the circuit and the completed circuit.
- Use a team approach to building and programming the PLC.

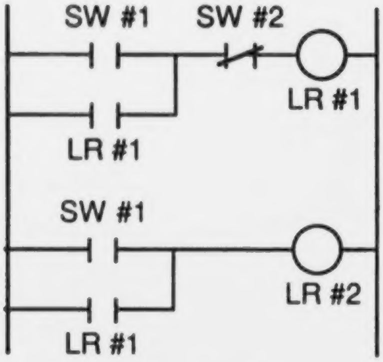
## Equipment/Supplies

1. An OMRON C-20 programmable controller
   Womack Machine Co.
   10860 Vandale
   San Antonio, TX 78216
   512 342 3231
2. Four normally open push-button switches
3. Four incandescent lamps
4. A thin piece of plywood or plastic on which to mount the switches and lamps
5. A supply of solid conductor wire

6. Soldering iron and solder

**Evaluation Key**

1. a. Press button #1.
   b. Lights #1 and #2 come on and stay on.
   c. Press button #2.
   d. All lights go off.

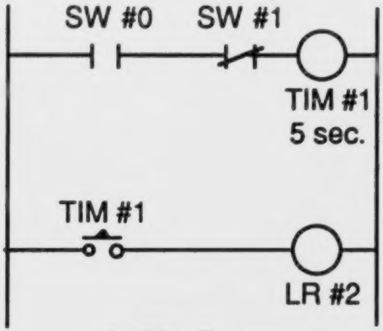

SW #1
SW #2
LR #1
LR #1
SW #1
LR #2
LR #1

Ladder diagram

| Address | Instruction | Data |
|---|---|---|
| 000 | LD | 001 |
| 001 | OR | 501 |
| 002 | AND NOT | 002 |
| 003 | OUT | 501 |
| 004 | LD | 001 |
| 005 | OR | 501 |
| 006 | OUT | 502 |

Program

2. a. Press button #0.
   b. Five seconds later, light #2 goes on and stays on.
   c. Press button #1.
   d Light #2 goes off.

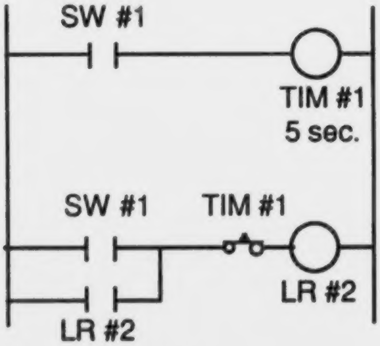

SW #0
SW #1
TIM #1
5 sec.
TIM #1
LR #2

Ladder diagram

| Address | Instruction | Data |
|---|---|---|
| 000 | LD | 000 |
| 001 | AND NOT | 001 |
| 002 | TIM | 001 |
|  |  | 050 |
| 003 | LD | TIM 001 |
| 004 | OUT | 502 |

Program

3. a. Press button #1.
   b. Light #2 goes on and stays on for 5 seconds.
   c. Light #2 goes off.

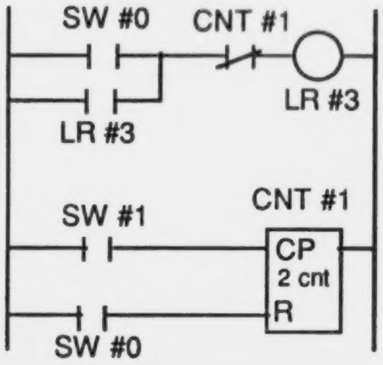


Ladder diagram

| Address | Instruction | Data |
|---|---|---|
| 000 | LD | 001 |
| 001 | TIM | 001 |
|  |  | 050 |
| 002 | LD | 001 |
| 003 | OR | 502 |
| 004 | AND NOT | TIM 001 |
| 005 | OUT | 502 |

Program

4. a. Press button #0.
   b. Light #3 goes on and stays on.
   c. After button #1 is pressed twice, light #3 goes off.


SW #0
CNT #1
LR #3
LR #3
SW #1
CNT #1
CP
2 cnt
R
SW #0

Ladder diagram

| Address | Instruction | Data |
|---|---|---|
| 000 | LD | 000 |
| 001 | OR | 503 |
| 002 | AND NOT | CNT 001 |
| 003 | OUT | 503 |
| 004 | LD | 001 |
| 005 | LD | 000 |
| 006 | CNT | 001 |
| 007 | | 002 |

Program

# PROGRAMMABLE LOGIC CONTROLLERS

*Learn how to write a working program, and understand how to use dedicated programmable logic controllers.*

---

## Objectives

- To understand the operation of programmable logic controllers
- To properly install and wire a programmable logic controller
- To write a working program using ladder logic on a programmable controller

## Vocabulary/Concepts Reinforced

- Programmable logic controller (PLC)
- Ladder diagrams
- Logic functions

## Equipment/Supplies

- A programmable controller
- Four normally open push-button switches
- Four incandescent lamps
- A thin piece of plywood or plastic on which to mount the switches and lamps
- A supply of solid conductor wire
- Soldering iron and solder (see instructor for safety procedures)

---

## Introduction

Programmable controllers are used to operate a wide variety of automatic industrial machines. These machines range from car washes to robots to rolling mills. The programmable controller is built around a microprocessor and contains all the other parts of a computer. By using the power of the computer, the programmable controller can perform rather complex tasks day in and day out. While each model of programmable controller may have slightly different capabilities, these specialized computers have some traits or specifications in common.

1. Almost all are programmed using "ladder logic" programming.
2. They use basic logic for their operation: AND—OR.
3. They will have a certain number of input "points" and output relays to perform their control function.
4. They will have "internal relays" that can be used to store information.
5. They will have built-in timers and counters.

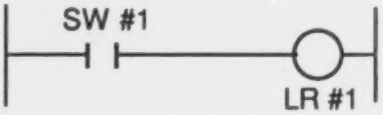
## Procedure

*Constructing the programmable logic I/O board:*

1. Drill four holes in the plywood or plastic sheet of the correct size to mount the particular switches you will be using. See your instructor for the correct procedure.
2. Drill four holes in the plywood or plastic sheet of the correct size to mount the incandescent lamps. See your instructor for the correct procedure.
3. Mount the four push-button switches onto the board. Number them from 0 to 3.
4. Mount the four lamps onto the board. Number them from 0 to 3.
5. Cut several pieces of wire to the appropriate lengths and strip the ends.

6. Carefully solder the wires to the push-button switches and lamps as indicated in the wiring diagram.
7. Connect the switches and lamps to the I/O ports of the programmable controller and the power supply as shown in the wiring diagram and schematic.

*Programming the programmable logic controller:*
Programmable logic controllers are programmed using what is called "ladder logic." The program is thought of as a ladder with several rungs. On the left of each rung is one or more input devices, while at the rightmost end is the output device. When the circuit is complete across a rung, the output device will be activated. For example, a push-button switch is connected to a lamp. The ladder logic diagram would look like this:

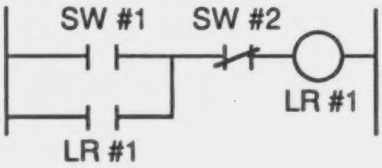


In the PLC, the program that would be entered for this ladder logic diagram would be:

| Address | Instruction | Data |
|---|---|---|
| 000 | LD | 001 |
| 001 | OUT | 501 |

When button SW#1 is pressed, it completes the circuit and the lamp LR#1 will come on. In this case, when the button is released, the light goes off.

The circuit in the example is so simple that it would not be very good use of a programmable controller. Suppose, however, that we had a more complex series of events in mind. For example, we want to turn on a light when a button is pushed, then keep it on until we press another button.
The ladder logic would look like this:



The program would be:

| Address | Instruction | Data |
|---|---|---|
| 000 | LD | 001 |
| 001 | OR | 501 |
| 002 | AND NOT | 002 |
| 003 | OUT | 501 |

When button SW #1 is pressed, it will activate the relay on light relay LR#1; this will, in turn, "latch" the circuit on via its corresponding input relay bypassing button SW #1. When button SW #2 is pressed, the circuit will be broken and the light will turn off.

The following indicates some of the functions and programming concepts used on the OMRON C-20 programmable controller.

### Evaluation

In each case, write a program on the PLC that will perform the sequence of operations:

1. a. Press button #1.
   b. Lights #1 and #2 come on and stay on.
   c. Press button #2.
   d. All lights go off.

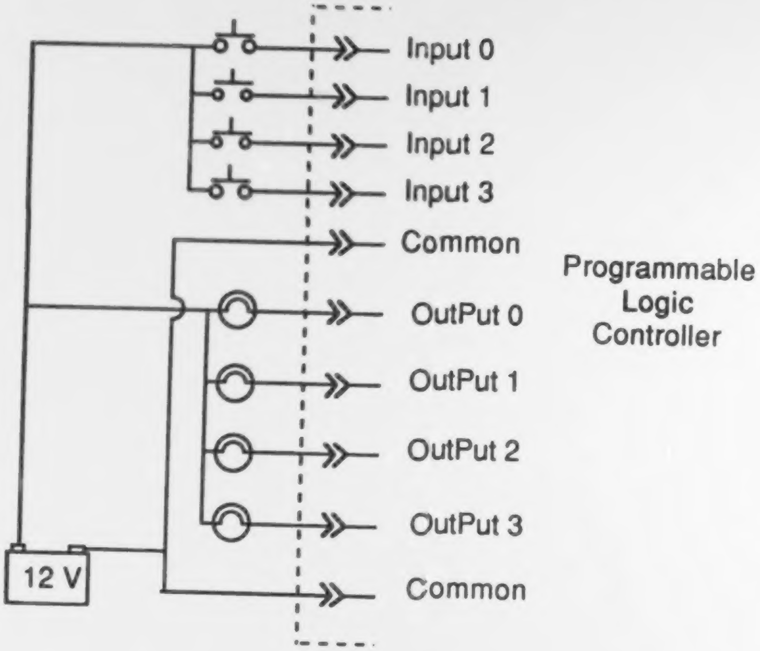
2. a. Press button #0.
   b. Five seconds later, light #2 goes on and stays on.
   c. Press button #1.
   d. Light #2 goes off.

3. a. Press button #1.
   b. Light #2 goes on and stays on for 5 seconds.
   c. Light #2 goes off.

4. a. Press button #0.
   b. Light #3 goes on and stays on.
   c. After button #1 is pressed twice, light #3 goes off.

### Support Materials

- *OMRON C-20 Programming Manual*, OMRON Electronics, 1986.
- Cox, Richard A. *Technician's Guide to Programmable Controllers*. Albany, N.Y.: Delmar, 1984.
- Schmitt, Neil M. and Farwell, Robert F. *Understanding Automation Systems*. Indianapolis: Howard W. Sams, 1984.
- Goetsch, David L. *Fundamentals of CIM Technology*. Albany, N.Y.: Delmar, 1988.


Input 0
Input 1
Input 2
Input 3
Common
OutPut 0
OutPut 1
OutPut 2
OutPut 3
Common
12 V
Programmable Logic Controller

(3-5 DAYS)

## STEPPER MOTORS

---

**Essential Elements:** Common: 8, 9
Specific: 1
**TAAS Objectives:** Mathematics: C 1, 2; O 1, 2; PS 2, 3
Language Arts: RC 1-5

---

### Activity Summary

Students use the A-BUS dual stepper motor controller card to experiment with stepper motors. This activity combines electrical wiring skills, the mechanics of computer interfacing, and computer programming. Students are involved in all phases of the interfacing experience from the mechanics of wiring to programming. The activity lends itself to a team approach with some students doing the actual construction while others work primarily on the programming.

The use of stepper motors is not limited to the demonstration board built in this activity. They may be used to construct different types of automation equipment, such as robots, conveyor belts, and parts movers.

### Teaching Tips

1. Use Module 14 in this guide as a background for the required number conversions.
2. Emphasize the relationship between the schematic drawing of the circuit and the completed circuit.
3. To simplify the programming, have every student use the same slot in the Apple or port in the IBM. This will eliminate the problem of different base addresses.
4. The introduction to the A-BUS system in Module 11 and the A-BUS user's manuals are invaluable references for all activities using the system.

### Instructional Strategy

Use a team approach to building and programming the security lock.

### Equipment/Supplies

1. A-BUS Dual Stepper Motor Controller (ST-143), two stepper motors (MO-103), cable, and A-BUS interface card for Apple II or IBM. The controller card (ST-143) and two stepper motors (MO-103 ) can be purchased from Alpha Products as a set (PA-181).
2. A thin piece of plywood or plastic on which to mount the stepper motors
3. Two potentiometer knobs for the stepper motors
4. A piece of plastic sheet or thin plywood from which to construct a set of pointers
5. Glue to attach the pointers to the potentiometer knobs

### Evaluation Key

The AppleSoft BASIC version of the programs below assumes that the A-BUS interface card is in slot 1, while the IBM BASICA or GW-BASIC versions assume that the interface card is set in the factory position (port 512).

1. Write a program that will drive one of the motors in one direction using the four-phase method.

**AppleSoft BASIC**

```
10  REM ONE DIRECTION 4 PHASE
20  FOR X = 0 TO 3 : READ A(X) : NEXT X
30  TEXT : HOME
40  PRINT "PRESS ANYKEY TO STOP"
50  FOR X = 0 TO 3
60  POKE 49408,A(X)
70  IF PEEK (49152) > 127 THEN 110
80  FOR Z = 0 TO 20 : NEXT Z
90  NEXT X
100 GOTO 50
110 POKE 49408,0
120 DATA 5,9,10,6
```

**BASICA or GW-BASIC**

```
10  REM One Direction 4 Phase
20  FOR X = 0 TO 3 : READ A(X) : NEXT X
30  CLS
40  PRINT "Press AnyKey to Stop"
50  FOR X = 0 TO 3
60  OUT 512,A(X)
70  IF LEN(INKEY$) <> 0 THEN 110
80  FOR Z = 0 TO 20 : NEXT Z
90  NEXT X
100 GOTO 50
110 OUT 512,0
120 DATA 5,9,10,6
```

2. Use the wave drive method to drive one motor.

**AppleSoft BASIC**

```
10  REM ONE DIRECTION WAVE DRIVE
20  FOR X = 0 TO 3 : READ A(X) : NEXT X
30  TEXT : HOME
40  PRINT "PRESS ANYKEY TO STOP"
50  FOR X = 0 TO 3
60  POKE 49408,A(X)
70  IF PEEK (49152) > 127 THEN 110
80  FOR Z = 0 TO 20 : NEXT Z
90  NEXT X
100 GOTO 50
110 POKE 49408,0
120 DATA 1,8,2,4
```

**BASICA or GW-BASIC**

```
10  REM One Direction Wave Drive
20  FOR X = 0 TO 3 : READ A(X) : NEXT X
30  CLS
40  PRINT "Press AnyKey to Stop"
50  FOR X = 0 TO 3
60  OUT 512,A(X)
70  IF LEN(INKEY$) <> 0 THEN 110
80  FOR Z = 0 TO 20 : NEXT Z
90  NEXT X
100 GOTO 50
110 OUT 512,0
120 DATA 1,8,2,4
```

3. Write a program that will drive one motor in the opposite direction from number 1 above using the four-phase method.

**AppleSoft BASIC**

```
10  REM OPPOSITE DIRECTION
20  FOR X = 0 TO 3 : READ A(X) : NEXT X
30  TEXT : HOME
40  PRINT "PRESS ANYKEY TO STOP"
50  FOR X = 3 TO 0 STEP -1
60  POKE 49408,A(X)
70  IF PEEK (49152) > 127 THEN 110
80  FOR Z = 0 TO 20 : NEXT Z
90  NEXT X
100 GOTO 50
110 POKE 49408,0
120 DATA 5,9,10,6
```

**BASICA or GW-BASIC**

```
10  REM Opposite Direction
20  FOR X = 0 TO 3 : READ A(X) : NEXT X
30  CLS
40  PRINT "Press AnyKey to Stop"
50  FOR X = 3 TO 0 STEP -1
60  OUT 512,A(X)
70  IF LEN(INKEY$) <> 0 THEN 110
80  FOR Z = 0 TO 20 : NEXT Z
90  NEXT X
100 GOTO 50
110 OUT 512,0
120 DATA 5,9,10,6
```

4. Drive two motors in one direction using the four-phase method.

**AppleSoft BASIC**

```
 10 REM TWO MOTORS ONE DIRECTION
 20 FOR X = 0 TO 3 : READ A(X) : NEXT X
 30 FOR X = 0 TO 3 : READ B(X) : NEXT X
 40 TEXT : HOME
 50 PRINT "PRESS ANYKEY TO STOP"
 60 FOR X = 0 TO 3
 70 POKE 49408,A(X)
 80 IF PEEK (49152) > 127 THEN 120
 90 FOR Z = 0 TO 20 : NEXT Z
100 NEXT X
110 GOTO 60
120 POKE 49408,0
130 DATA 5,9,10,6
140 DATA 80,144,160,96
```

**BASICA or GW-BASIC**

```
 10 REM Two Motors One Direction
 20 FOR X = 0 TO 3 : READ A(X) : NEXT X
 30 FOR X = 0 TO 3 : READ B(X) : NEXT X
 40 CLS
 50 PRINT "Press AnyKey to Stop"
 60 FOR X = 0 TO 3
 70 OUT  512,A(X)
 80 IF LEN(INKEY$) <> 0 THEN 120
 90 FOR Z = 0 TO 20 : NEXT Z
100 NEXT X
110 GOTO 60
120 OUT  512,0
130 DATA 5,9,10,6
140 DATA 80,144,160,96
```

5. Write a program that will allow the user to input a number of steps and a direction from the keyboard. When the user presses return, the motor will make the requested move.

**AppleSoft BASIC**

```
 10 REM TWO MOTORS ONE DIRECTION
 20 FOR X = 0 TO 3 : READ A(X) : NEXT X
 30 TEXT : HOME
 40 INPUT "DIRECTION R/L -> ";D$
 50 IF D$ <> "R" AND D$ <> "L" THEN 40
 60 INPUT "DISTANCE (0-300) -> ";D
 70 IF D < 1 OR D > 300 THEN 60
 80 IF D$ = "L" THEN 130
 90 C = C + 1 : IF C > D THEN 200
100 X = X + 1 : IF X > 3 THEN X = 0
110 GOSUB 170
120 GOTO 90
130 C = C + 1 : IF C > D THEN 200
140 X = X - 1 : IF X < 0 THEN X = 3
150 GOSUB 170
160 GOTO 130
170 POKE 49408,A(X)
180 FOR Z = 0 TO 20 : NEXT Z
190 RETURN
200 POKE 49408,0
210 DATA 5,9,10,6
```

**BASICA or GW-BASIC**

```
 10 REM Direction and Distance
 20 FOR X = 0 TO 3 : READ A(X) : NEXT X
 30 CLS
 40 INPUT "Direction R/L -> ";D$
 50 IF D$ <> "R" AND D$ <> "L" THEN 40
 60 INPUT "Distance (0-300) -> ";D
 70 IF D < 1 OR D > 300 THEN 60
 80 IF D$ = "L" THEN 130
 90 C = C + 1 : IF C > D THEN 200
100 X = X + 1 : IF X > 3 THEN X = 0
110 GOSUB 170
120 GOTO 90
130 C = C + 1 : IF C > D THEN 200
140 X = X - 1 : IF X < 0 THEN X = 3
150 GOSUB 170
160 GOTO 130
170 OUT 512, A(X)
180 FOR Z = 0 TO 20 : NEXT Z
190 RETURN
200 OUT 512,0
210 DATA 5,9,10,6
```

# STEPPER MOTORS

*Learn how to write programs that operate two stepper motors.*

---

## Objectives

- To understand the operation of stepper motors
- To make proper wiring connections for a stepper motor to its interface card
- To write programs in BASIC which will operate one or more stepper motors

## Vocabulary/Concepts Reinforced

- Stepper motor
- Four-phase drive
- Wave drive

## Equipment/Supplies

- A-BUS Dual Stepper Motor Controller (ST-143), two stepper motors (MO-103), cable, and A-BUS interface card for Apple II or IBM
- A thin piece of plywood or plastic on which to mount the stepper motors
- Four mounting screws for stepper motors
- Two potentiometer knobs for the stepper motors
- A piece of plastic sheet or thin plywood from which to construct a set of pointers
- Glue to attach the pointers to the potentiometer knobs

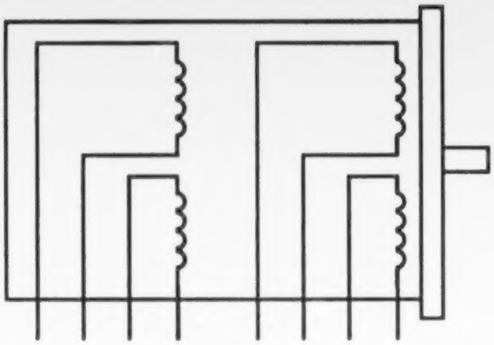
---

## Introduction

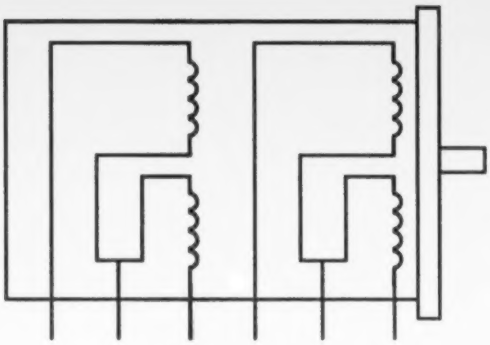
Unlike conventional motors, which move continuously, a stepper motor moves in discrete steps. The stepper motor allows control of position, speed, and direction. This type of motor can even be used to "hold" in a given position. These capabilities have many uses, such as driving the printer head in a dot-matrix printer, driving the platen in a printer, moving the pen in a plotter, and powering the feed in a CNC machine tool. In each case, the precision and control offered by the stepper make it the only choice.

Each step the stepper motor takes is a certain percentage of a complete rotation. Some steppers can divide a rotation into 48 steps, while others can go as high as several hundred steps. For example, the stepper motors that are used in this activity are capable of making 48 steps per revolution or 360°/48 = 7.5° per step.

There are several types of stepper motors—variable reluctance, unidirectional, and Sawyer machines. This activity will work with only the unipolar (bifilar) type of motor. This type of motor has four windings and a stack of two rotors. The windings are wired so that they usually provide eight wires coming out of the motor. Sometimes, a pair of the wires are connected internally so that there are only six wires coming out of the motor. They operate the same, however. Schematics of the two variations are shown on the next page:

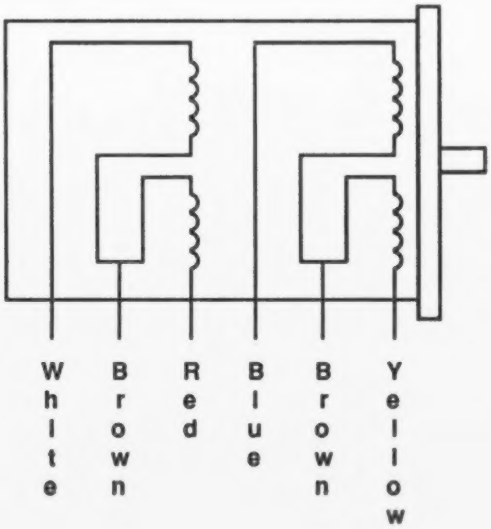


**Eight Wire Motor**



**Six Wire Motor**

In order to simplify installation, the wires that extend from the stepper are color coded. The steppers used in this activity are color-coded as follows:



## Procedure

*Wiring the stepper motors:*

1. Drill holes and mount the two stepper motors on the thin piece of plywood or plastic. See the instructor for the correct procedure.
2. Cut out a piece of thin plywood or plastic sheet to the shape indicated in the drawing for the pointer. Drill the 1/2" hole to clear the stepper motor's shaft.
3. Glue the pointer to the back of the knob so that the holes line up.
4. Attach the knob onto the stepper motor's shaft.
5. Connect the stepper motor leads to the controller card as shown in the wiring diagram.

*Programming the stepper motor controller:*

The stepper motors respond when a series of digital numbers are output from the computer. The response of each stepper motor is determined by the *sequence* of numbers that are sent.

The most common drive method used with stepper motors is called **four-phase drive**, because it activates all four windings in the motor at once. This is accomplished by sending the proper sequence of numbers to the controller. The table below indicates the proper numbers for each of the two motors:

| Value to Send | |
|---|---|
| Motor 1 | Motor 2 |
| 5 | 80 |
| 9 | 144 |
| 10 | 160 |
| 6 | 96 |

For example, sending the sequence 5 -> 9 -> 10 -> 6 -> 5 -> 9, would cause the number 1 motor to rotate through five steps in one direction. As you can see, repeating the sequence causes the motor to continue to rotate. Reversing the sequence, 5 -> 6 -> 10 -> 9, would reverse the direction of rotation.

In order to rotate both motors, simple add together the desired values, 85 -> 153 -> 170 -> etc. By combining the right values in the right sequence, you can control either or both motors simultaneously.

Another common drive method used with stepper motors is called **wave drive**, because it activates each of the four windings one after another. This method, however, does not produce the same amount of power as four-phase drive. Movement in this method is also accomplished by sending the proper sequence of numbers to the controller. The table below indicates the proper numbers for each of the two motors:

| Value to Send | |
|---|---|
| Motor 1 | Motor 2 |
| 1 | 16 |
| 8 | 128 |
| 2 | 32 |
| 4 | 64 |

Direction and motor choice are the same as for four-phase drive.

The **speed** of a stepper motor is determined by how fast the driving sequence of numbers is sent to the controller. The faster the sequence is sent, the faster the motor will rotate. Stepper motors do have a limit to their top speed. This occurs when the motor begins to "slip." At this point the motor will miss steps or completely stop and only "jitter." There is really no minimum speed for a stepper. It can be moved one step at a time or held in a given position indefinitely.

The actual method of sending values to the stepper motor controller card depends on the kind of computer you are using.

For Apple II computers in AppleSoft BASIC:

1. The slot holding the A-BUS interface card determines the "base address." These are:

| | |
|---|---|
| Slot 1 | 49408 |
| Slot 2 | 49664 |
| Slot 3 | 49920 |
| Slot 4 | 50176 |
| Slot 5 | 50432 |
| Slot 6 | 50688 |
| Slot 7 | 50944 |

2. A POKE statement is then used to send the desired value to the card. With the interface card in slot 1, the following program illustrates a simple four-phase sequence for motor #1. A short delay loop must be used between each step. The motor will continue to rotate until Cntrl-C is pressed.

```
10 POKE 49408, 5
20 FOR Z = 0 TO 200 : NEXT Z
30 POKE 49408, 9
40 FOR Z = 0 TO 200 : NEXT Z
50 POKE 49408, 10
60 FOR Z = 0 TO 200 : NEXT Z
70 POKE 49408, 6
80 FOR Z = 0 TO 200 : NEXT Z
90 GOTO 10
```

For IBM and compatible computers using BASICA or GW-BASIC:

1. The interface card in the IBM is set for a particular I/O port. The ports that work best in most IBMs and compatibles are 512 to 576.

2. An OUT statement is then used to send the desired value to the card. The following program illustrates a simple four-phase sequence for motor #1. A short delay loop must be used between each step. The motor will continue to rotate until Cntrl-C is pressed.

```
10 OUT  512, 5
20 FOR Z = 0 TO 200 : NEXT Z
30 OUT  512, 9
40 FOR Z = 0 TO 200 : NEXT Z
50 OUT  512, 10
60 FOR Z = 0 TO 200 : NEXT Z
70 OUT  512, 6
80 FOR Z = 0 TO 200 : NEXT Z
90 GOTO 10
```

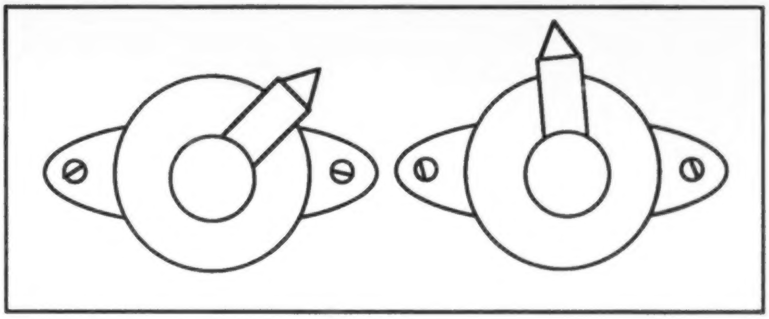
### Evaluation

1. Write a program that will drive one of the motors in one direction using the four-phase method.
2. Use the wave drive method to drive one motor.
3. Write a program that will drive one motor in the opposite direction from number 1 above using the four-phase method.
4. Drive two motors in one direction using the four-phase method.

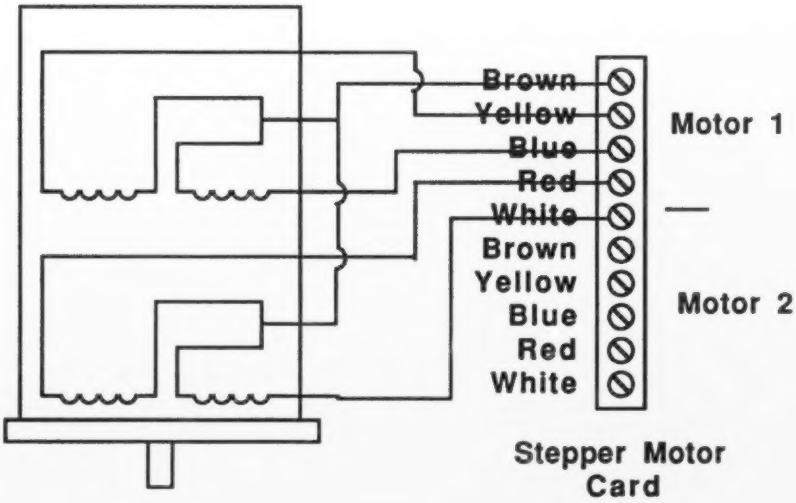
5. Write a program that will allow the user to input a number of steps and a direction from the keyboard. When the user presses return, the motor will make the requested move.

## Support Materials

- The introduction to the A-BUS from this guide (Module 11)
- BASIC programming manual for Apple II or IBM



Mounting Motors


Brown
Yellow
Blue
Red
White
Brown
Yellow
Blue
Red
White
Motor 1
—
Motor 2
Stepper Motor Card

Wiring Diagram for One Motor

ELECTRICITY/ELECTRONICS SYSTEMS
INSTRUCTOR'S RESOURCE SHEET 22
(2 DAYS)

# CATALOG PRICING

---

**Essential Elements:** Common: 8A, 10B, 10C,
Specific: 3, 8, 9.
**TAAS Objectives:** Mathematics: C 1, 4; O 1, 4; PS 2, 3

---

## Activity Summary

Students will use a catalog to look up the cost and availability of materials for a specified project. Students will learn to calculate the cost of a project and make sure all items are available before starting construction. Students will improve their knowledge of units of measurements and identification of parts.

## Teaching Tips

1. Use a catalog that is easily available, has lots of pictures, and a variety of parts. Radio Shack catalogs work well.
2. Have students obtain their own catalog.
3. Have a catalog for each student.
4. If a student cannot obtain a catalog, ask other students to pick up extras for them.
5. Show packages of parts, and calculate prices as an example.

## Instructional Strategy

- Although the exercise is designed to improve math skills, the use of a calculator could help to improve other skills.
- Encourage students to compare prices in other catalogs so they know of more than one place to buy parts.
- Have students note that some parts of the same values come in different housings.

## Equipment/Supplies

1. Copies of Project Cost Sheet handout
2. Catalogs

## Evaluation Key

| | |
|---|---|
| 1. Neatness | 5% |
| 2. Quantity | 5% |
| 3. Description | 5% |
| 4. Page numbers | 5% |
| 5. Number per package | 5% |
| 6. Cost per package | 5% |
| 7. Cost per item | 20% |
| 8. Cost for project | 20% |
| 9. Subtotal | 20% |
| 10. Tax and total | 10% |

# CATALOG PRICING

*Use electronics catalogs to calculate the cost of a project and check for availability of materials.*

---

## Objectives

- To increase the ability to recognize parts
- To recognize the cost of materials
- To show how parts can become outdated and no longer be available
- To develop skills in use of part values and measurements
- To develop mathematic skills (addition, subtraction, multiplication, and division)
- To develop skills in reading charts

## Vocabulary/Concepts

- Resistor—a device that opposes current.
- Ohms—the unit of measurement of resistance.
- Wattage rating—the maximum power that a device can safely handle.
- Kilo—a prefix representing $10^3$.
- Mega—a prefix representing $10^6$.
- Tolerance—the permissible deviation from a specified value.
- Capacitor—a device that stores electrons.
- Farad—the unit of measurement of capacitance.
- Micro—a prefix representing $10^{-6}$.
- Pica—a prefix representing $10^{-12}$.
- Working voltage—the recommended maximum voltage of operation.

## Equipment/Supplies

- "Project Cost Sheet" handout
- Catalogs

---

## Introduction

Count the cost before beginning a project. Some projects may cost more to make than they cost ready-to-use, and parts to make the projects are not always available. This activity allows you to check catalogs for the price and availability of parts. It will also allow you to see pictures of parts and examine their range of values.

## Procedure

1. Select a project with several different types of parts.
2. Fill in the columns on quantity, description, and value with the information from the parts list.
3. Fill in the columns on number per package and cost per package with the use of an electronics catalog.
4. Calculate the cost per item, total item cost, and record answers.
5. Calculate the subtotal cost of the project, add sales tax, and record the total cost.

## Evaluation

Points can be given for each entry or group of entries. Points will vary with the number of parts recorded.

student's name ______________________

catalog ______________________

# PROJECT COST SHEET

| Quantity | Description | Catalog page | Number per package | cost per package | cost per item | cost for project |
|---|---|---|---|---|---|---|
| | | | | | | |
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| | | | | | | |
| | | | | | subtotal | |
| | | | | | tax | |
| | | | | | total | |

# DIGITAL DICE

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**Essential Elements:** Common: 2C-L, 4B-F, 6A, 6B, 8F, 9A
Specific: 1, 3, 9, 12-14
**TAAS Objectives:** Mathematics: C 1, 4; O 1-4; PS 2, 3

---

## Activity Summary

Students will construct a digital dice. They will start with the schematic and develop a PC board layout, make a PC board, mount parts, and place the project in a case. The students will be exposed to many processes of manufacturing and have an opportunity to see how resistor-capacitor circuits are used in binary circuits. This activity also explores the use of digital counters, decoders, and displays.

## Teaching Tips

1. Students should be capable of identifying parts and have construction skills (soldering, use of hand tools, and use of drill press) before beginning this activity.
2. Each student needs their own project.
3. Instructor should build a digital dice and have it on display before starting the activity.

## Instructional Strategy

- There are several illustrations included in this activity that can be given to students if they have problems.
- Allow the students to try each area before giving them the illustrations.
- Have a deadline for each area, and give the students a copy of the illustrations if they have not been able to complete the area, so they don't fall behind.

## Equipment/Supplies

1. Soldering iron (20-40 watt), one per 2 or 3 students
2. 60/40 rosin core solder
3. Diagonals
4. Etching solution
5. Plastic tray
6. X-acto knives
7. Steel wool (fine)
8. Carbon paper
9. Masking tape
10. Resist ink

## Parts kit for digital dice:

1. 1—2x4 in. copper-clad board
2. 2—560-ohm 1/2-watt resistors
3. 1—10 mF electrolytic capacitor
4. 1—7408 Quad AND gate IC
5. 7—Jumbo red LED
6. 1—spst slide switch
7. 12"—22 ga. hookup wire
8. 7—220-ohm 1/2-watt resistors
9. 1—7404 Hex inverter IC

10. 1—7490 decade counter IC
11. 1—Push-button switch N/O
12. 1—9V battery clip

**Evaluation**

| | | |
|---|---|---|
| 1. | PC board layout | 30% |
| 2. | PC board | 30% |
| 3. | Assembly | 20% |
| 4. | Operation | 10% |
| 5. | Troubleshooting | 10% |

# DIGITAL DICE

*Build an electronic counter with an output that displays a count of one to six in a dice pattern.*

---

## Objectives

- To increase skills in the use of tools used in the electronic field
- To develop the recognition and use of common electrical parts
- To explore the use of clocks
- To explore the use of counters
- To explore the use of decoders
- To explore the use of displays
- To show how binary counting is accomplished

## Vocabulary/Concepts Reinforced

- Digital—circuits in which the output varies in discrete steps (pulses or on-off operations).
- Binary—a numbering system using a base number of 2.
- Clock—a pulse generator or timing device that provides a continuous series of pulses.
- Counter—a circuit that counts input pulses.
- Decoder—a circuit that converts coded information into a more usable form.
- Display—a visual presentation of a received signal.
- Inverter—a circuit that takes in a signal and puts out an opposite signal.
- Gate—a circuit that controls the output by control of the input.

## Equipment/Supplies

- Soldering iron (20-40 watt), one per 2 or 3 students
- 60/40 rosin core solder
- Diagonals
- Etching solution
- Plastic tray
- X-acto knives
- Steel wool (fine)
- Carbon paper
- Masking tape
- Resist ink

## Parts kit for digital dice

- 1—2x4 in. copper-clad board
- 2—560-ohm 1/2-watt resistors
- 1—10 mF electrolytic capacitor
- 1—7408 Quad AND gate IC
- 7—Jumbo red LED
- 1—spst slide switch
- 12"—22 ga. hookup wire
- 7—220-ohm 1/2-watt resistors
- 1—7404 Hex inverter IC
- 1—7490 decade counter IC
- 1—Push-button switch N/O
- 1—9V battery clip

---

## Introduction

In order to understand how computers can count and handle data, you must have an understanding of digital electronics and binary. This activity introduces these concepts at a very elementary level. The project is arranged so that the major areas of the PC board can be easily found and the data can be traced through the circuit.

The activity allows you to make a project starting with the schematic, design a layout, make the PC board, and then assemble the parts. Illustrations are available to keep you going if you should need them.

## Procedure

1. Make a copy of the schematic.
2. Purchase the parts or use the shapes given on the illustrations to draw the arrangement of parts and holes in a 2x4-inch space. Use the enlarged drawing to help arrange the parts.
3. Trace the locations of the holes to the back side of the paper. This is the copper side of the PC board.
4. Use the enlarged drawing of the path layout to put paths on your actual size drawing.
5. Have someone else look over your drawing for mistakes.
6. Transfer your layout to a piece of copper-clad board, and etch it.
7. Drill holes in the board.
8. Check the board for shorted or open paths.
9. Mount the parts on the PC board.
10. Place the project in a case.

## Evaluation

| | |
|---|---|
| • PC board layout | 30% |
| • PC board | 30% |
| • Assembly | 20% |
| • Operation | 10% |
| • Troubleshooting | 10% |

## Support Materials

- Figure 1 is a copy of the schematic.
- Figure 2 is an enlarged drawing of the parts side of the board.
- Figure 3 is an enlarged drawing of the copper side of the board.
- Figure 4 is an actual size drawing of the copper side, showing the location of parts.
- Figure 5 is an actual size drawing of the copper side, showing the location of the holes.
- Figure 6 is an actual size drawing of a completed layout.
- Figure 7 is an actual size drawing showing the location of all parts, looking at the parts side of the board.

# DIGITAL DICE

Designed by: Ivan Tunon

## Parts list

| | |
|---|---|
| R1, R2 | 360 ohms, 1/2 watts |
| R3-R9 | 220 ohms, 1/2 watts |
| C1 | 10 mfd |
| L1, L2 | Jumbo red LED |
| U1 | 7404 Hex inverter |
| U2 | 7490 Decade counter |
| U3 | 7408 Quad AND Gate |
| S1 | SPST Push button, NO |
| S2 | SPST slide switch |
| B1 | 9v battery clip |

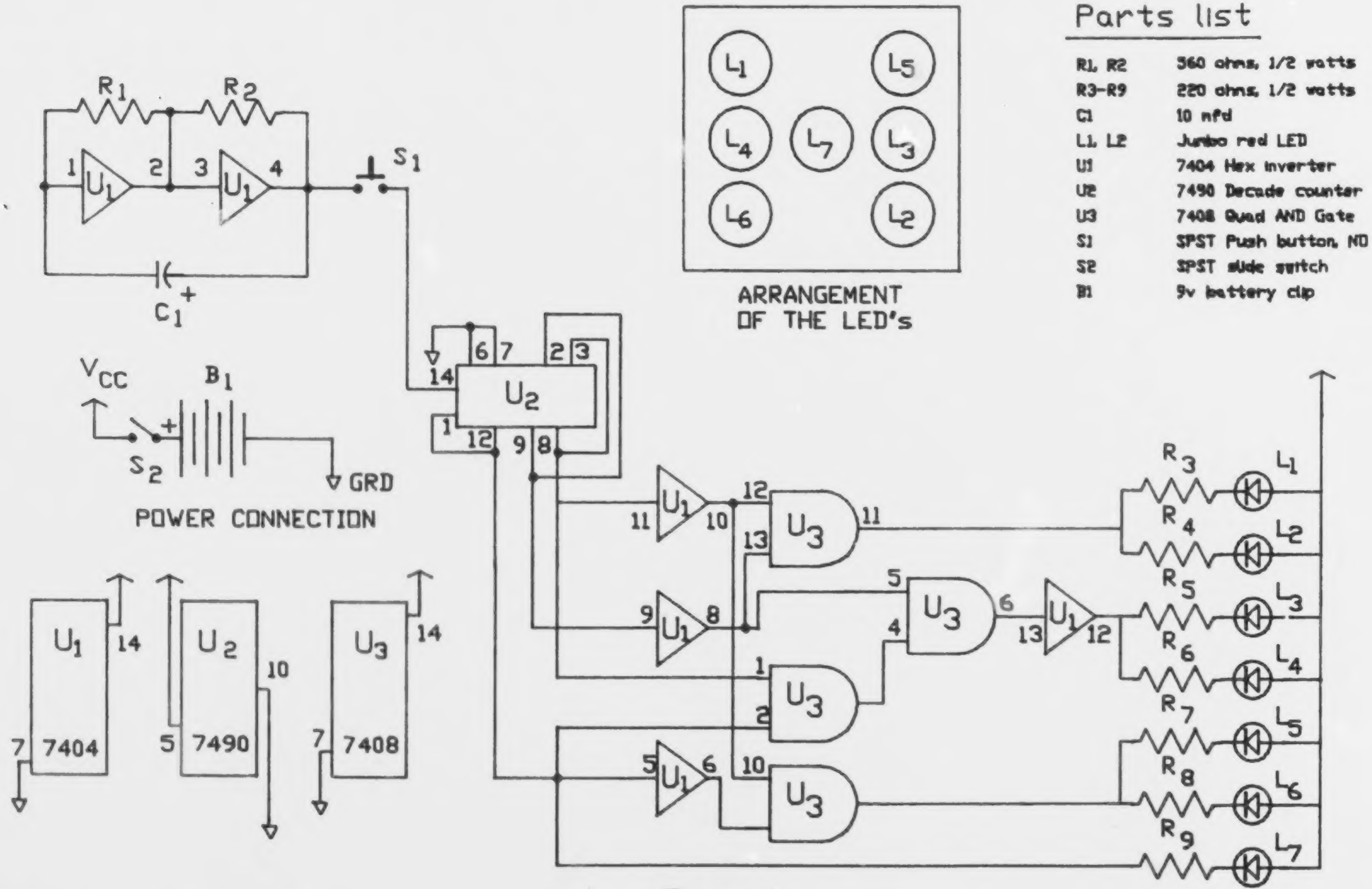

R1
R2
U1
U1
1
2
3
4
S1
C1
+
L1
L5
L4
L7
L3
L6
L2
ARRANGEMENT OF THE LED's
U2
6
7
2
3
14
1
12
9
8
VCC
B1
+
S2
GRD
POWER CONNECTION
U1
U3
R3
R4
R5
R6
R7
R8
R9
L1
L2
L3
L4
L5
L6
L7
11
10
12
13
9
8
5
4
6
13
12
1
2
5
6
10
U1
14
7
7404
U2
10
5
7490
U3
14
7
7408

Figure 1

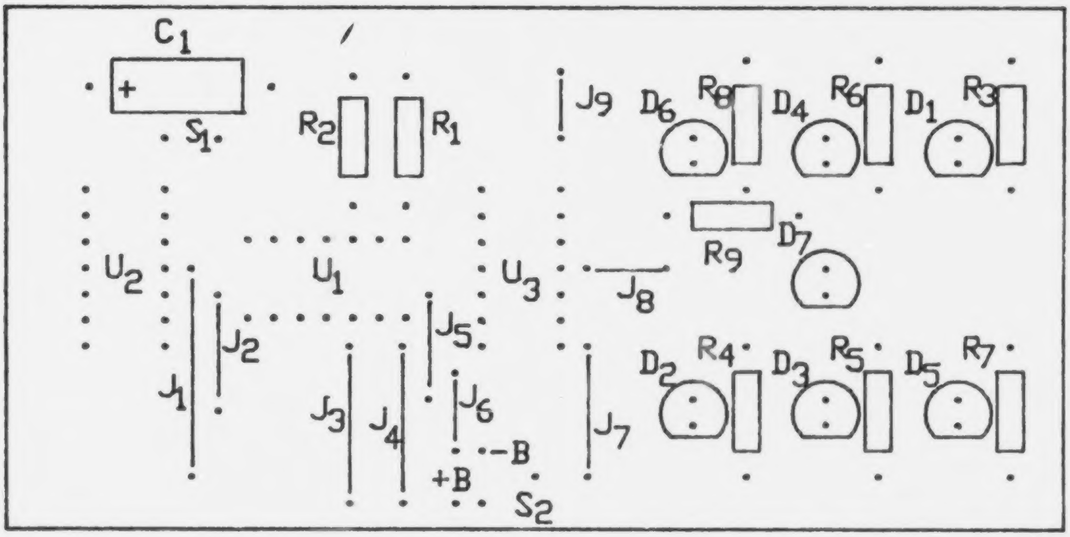

$C_1$
+
$S_1$
$R_2$
$R_1$
$J_9$
$D_6$
$R_8$
$D_4$
$R_6$
$D_1$
$R_3$
$R_9$
$D_7$
$U_2$
$U_1$
$U_3$
$J_8$
$J_2$
$J_5$
$J_1$
$J_3$
$J_4$
$J_6$
-B
+B
$S_2$
$J_7$
$D_2$
$R_4$
$D_3$
$R_5$
$D_5$
$R_7$

Fig. 2

Enlarged view of part side of pc board, showing arrangement of parts.

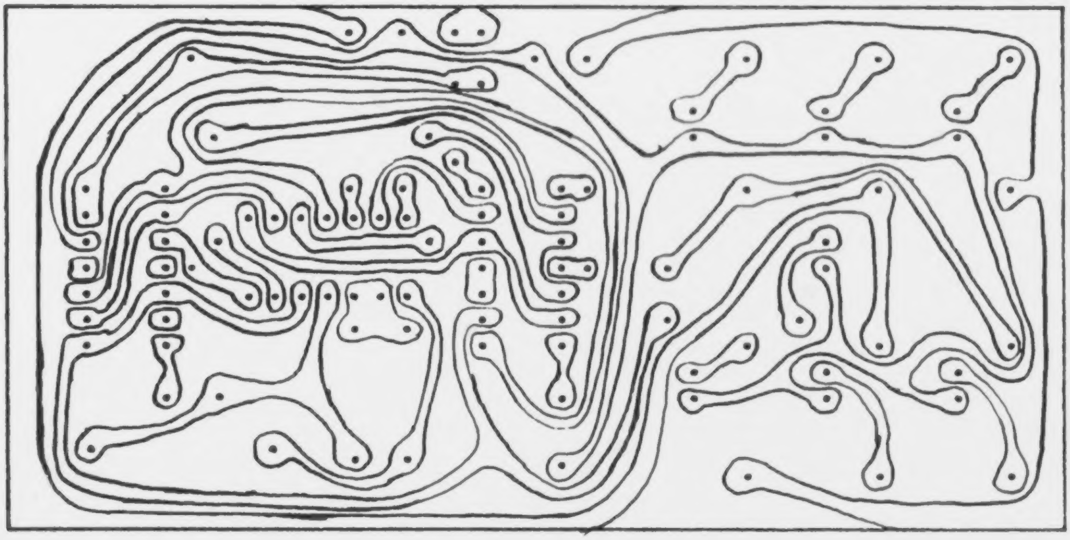


Fig. 3

Enlarged view of copper side of pc board, showing copper paths.

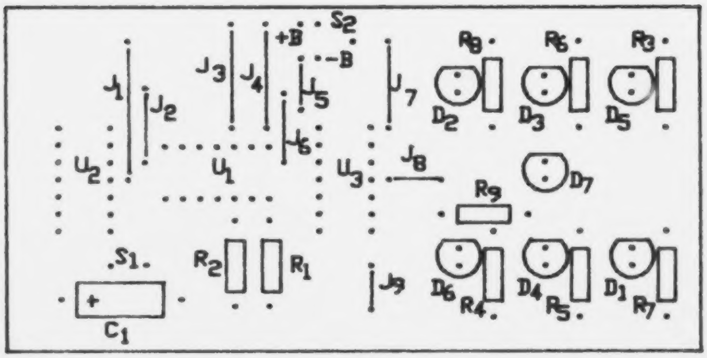

S2
+B
-B
R8
R6
R3
J1
J2
J3
J4
J5
J6
J7
D2
D3
D5
U2
U1
U3
J8
R9
D7
S1
R2
R1
J9
D6
R4
D4
R5
D1
R7
+
C1

Fig. 4

Actual size drawing of the copper side, showing the location of parts on the other side.

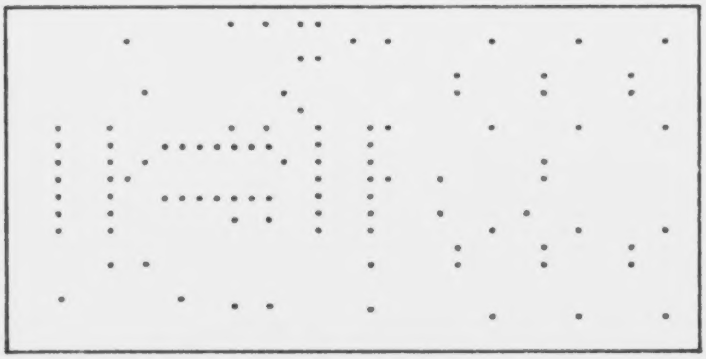


Fig. 5

Actual size drawing of the copper side, showing the location of holes

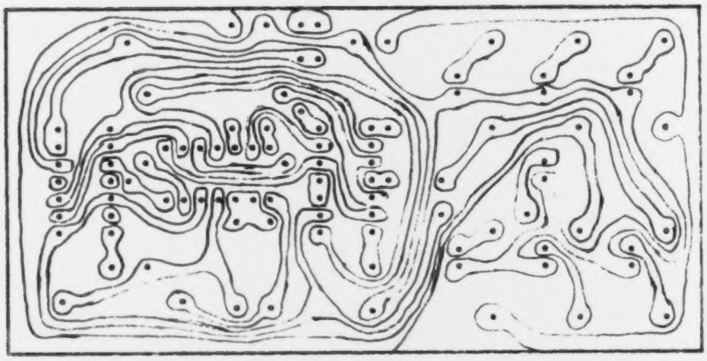


Fig. 6

Actual size drawing of a completed layout, looking at the copper side of the board.

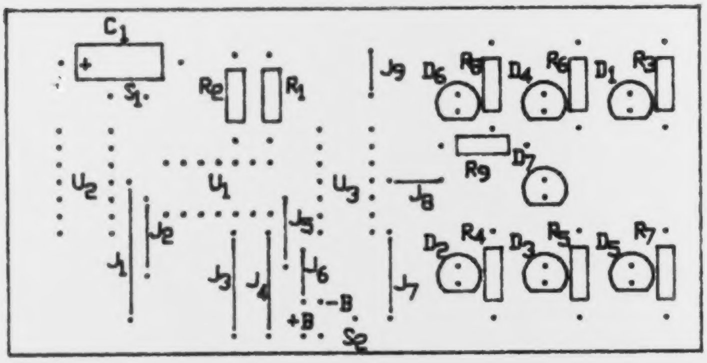

C1
+
S1
R2
R1
J9
D6
R8
D4
R6
D1
R3
U2
U1
U3
R9
D7
J8
J2
J5
J1
J3
J4
J6
-B
+B
S2
J7
D2
R4
D3
R5
D5
R7

Fig. 7

Actual size drawing, showing the location of all parts, looking at the part side of the board.

ELECTRICITY/ELECTRONICS SYSTEMS
INSTRUCTOR'S RESOURCE SHEET 24
(1 WEEK)

# MAKING PRINTED CIRCUIT BOARDS

---

**Essential Elements:** Common: 2C-L, 4A-F, 6A-C, 8F, 9C
Specific: 1, 3, 9
**TAAS Objectives:** Mathematics: C 4

---

## Activity Summary

Students will draw the artwork for a printed circuit board and then transfer that layout to a copper board, etch the board, drill holes, and then construct the project.

## Teaching Tips

1. Student should be familiar with schematics, components, PC boards, and construction of projects before beginning this activity.
2. Allow students to help each other. This is sometimes an opportunity for lower academic students to lead.
3. Have students compare results, and point out good and bad points. This helps the students see that there can be more than one right answer.

## Instructional Strategy

- Have all students do the same project the first time.
- Stress the need for small area (cost of board, size of case, etc.). When mass producing, a few pennies saved on each project can greatly increase profits.
- Use a project that has few parts, lays out easily, and can be done without jumpers to begin with.
- The shape and size of the board can be given or left to the student. Exact size drawings of parts and hole placement can be given to the student instead of the actual parts. Lacquer thinner can be put in a squirt-type oil can with the tip partially clogged with solder to make it easier to use.
- Before beginning the activity, have each student paint his or her initials on a one-inch square of copper-clad board and etch it to see how the process works.

## Equipment/Supplies

1. Copper-clad board
2. Masking tape
3. Steel wool
4. Carbon paper
5. Resist ink (fingernail polish)
6. Lacquer thinner
7. Paper towels
8. Etching solution
9. Plastic tray with flat bottom
10. X-acto knife

## Evaluation Key

| | |
|---|---|
| 1. Step 1 | 10% |
| 2. Step 2 | 10% |
| 3. Steps 3, 4 | 20% |

| | |
|---|---|
| 4. Step 5 | 10% |
| 5. Steps 6, 7 | 10% |
| 6. Step 8-11 | 10% |
| 7. Step 12-16 | 20% |
| 8. Step 17 | 10% |
| 9. Steps 18, 19 | Graded as a separate assignment |

# MAKING PRINTED CIRCUIT BOARDS

*Design and build your own printed circuit boards.*

---

## Objectives

- To design the artwork for a printed circuit board
- To transfer the artwork to copper-clad board and etch the paths on the board

## Vocabulary/Concepts Reinforced

- Printed circuit board—a thin sheet of insulation board that has thin copper paths that connect parts together.
- Copper-clad board—insulated board that is covered by a thin sheet of copper.
- Artwork—the drawings and design that go into making a PC board layout.
- Resist ink—a solution used to cover copper to keep the etching solution from reaching it.
- Etching solution—ferric chloride or ammonium persulphate which reacts with copper to remove it from desired areas.
- Layout—a drawing showing the location of holes and the shape of copper paths.
- Copper pad—copper that surrounds the holes and to which the leads of parts are soldered.
- Copper paths—the copper that connects the pads together.

## Equipment/Supplies

- Copper-clad board
- Masking tape
- Steel wool
- Carbon paper
- Resist ink (fingernail polish)
- Lacquer thinner
- Paper towels
- Etching solution
- Plastic tray with flat bottom
- X-acto knife

---

## Introduction

A printed circuit board is a thin board made of an insulation-type material on which thin sheet copper is bonded to connect parts together. Parts are mounted on the board by placing the leads through holes drilled in the board and then soldering the leads to the copper paths.

Before a PC board can be made, the artwork must be designed. The artwork is the actual shape and arrangement of the copper paths that are needed to connect the parts together as shown on the schematic.

Some parts are not mounted on the PC board. Switches, speakers, battery holders and potentiometers are sometimes mounted elsewhere and connected to the PC board by wires.

Parts should be mounted as close together as possible, but remember to allow room for air to circulate around parts that might overheat during operation of the project.

The board should be made as small as possible, or it can be designed to fit a predetermined shape.

### Procedure

1. Make a copy of the schematic, file the original in a safe place, and work from the copy.
2. Replace the schematic symbols with the actual size outline of the part, showing where holes should be drilled. Remember that some parts are connected to the board by wires and not mounted directly on the board.
3. Regroup parts to a smaller area, and reroute any paths that cross on the schematic but are not connected.
4. Regroup parts again to improve arrangement or decrease size.
5. Replace lines connecting parts with copper paths.
6. Trace paths without outline of parts. Remember, this is looking at the parts side of the circuit board.
7. Turn the paper over, and trace the layout to the back side of the paper. This is the copper side of the board and the layout used to make your PC board.
8. Cut a piece of copper clad board to match your layout.
9. Clean the copper with steel wool or a pencil eraser.
10. Cover the copper with a single layer of masking tape.
11. Using carbon paper, transfer the layout from step 7 to the masking tape.
12. Mark the location of holes with a center punch, and then cut out the paths with an X-acto knife.
13. Remove the tape covering the paths, and paint the exposed copper with resist ink (fingernail polish works fine).
14. Remove the remaining tape. Copper paths are now under the resist ink.
15. Place the copper-clad board in a plastic tray with enough etching solution to cover the board. Etching takes from ten minutes to a hour, depending on how strong the etching solution is, the temperature of the solution, and how often the solution is agitated.
16. Remove the board from the etching solution, and rinse with water; then use lacquer thinner to remove the resist ink.
17. Drill holes in the board with a #56 drill.
18. The parts can now be placed on the board and soldered in place.
19. Place the project in a suitable case and enjoy your project.

### Evaluation

| | |
|---|---|
| Step 1 | 10% |
| Step 2 | 10% |
| Steps 3, 4 | 20% |
| Step 5 | 10% |
| Steps 6, 7 | 10% |
| Steps 8-11 | 10% |
| Steps 12-16 | 20% |
| Step 17 | 10% |
| Steps 18, 19 | Graded as a separate assignment |

ELECTRICITY/ELECTRONICS SYSTEMS
INSTRUCTOR'S RESOURCE SHEET 25
(3 DAYS)

# MAKING AN ELECTRIC MOTOR

---

**Essential Elements:** Common: 2, 6-9
Specific: 1, 2, 6
**TAAS Objectives:** Language Arts: RC 1-6

---

## Activity Summary

This activity is intended to provide students with a basic project in electromagnetism. Students will construct and operate a small electric motor and make several observations about its performance.

## Teaching Tips

1. Go through the activity yourself and build the motor.
2. Make sure that you have enough materials to provide each group or individual with the necessary parts to complete the project. If possible, have your students bring some of the materials from home.
3. Upon completion of the activity place several of the motors on display for other students to view them.
4. Review any necessary safety procedures that you feel are needed for your particular students.

## Instructional Strategy

- Lecture to present the topic to students.
- Use the project as either a small group or individual activity.

## Equipment/Supplies

1. Medicine dropper
2. Modeling clay (stick form)
3. Bar magnets
4. 16d box nails (bright)
5. 4d casing or box nails
6. Insulated bell wire or magnet wire (18 or 20 gauge)
7. Electrical tape
8. Pieces of corrugated cardboard
9. Aluminum sheet metal
10. Plywood (1/4" x 6" x 8" pieces)
11. Batteries (one 6-volt or four 1.5-volt #6 dry cells)

## Evaluation Key

Instructor evaluation of student performance on this project will be based on participation in and completion of the activity.

# MAKING AN ELECTRIC MOTOR

*Learn how electromagnetism works by constructing an electric motor.*

---

## Objectives

- To develop a better understanding of how the electric motor converts electrical energy into energy of motion
- To develop an understanding of electromagnetism

## Vocabulary/Concepts Reinforced

- Armature—the part of an electric motor which consists of coils of wire wrapped around a soft metal bar or rod creating an electromagnet which can be made to turn a shaft.
- Electromagnet—a magnetic created by wrapping coils of wire around a metal core and then passing an electrical current through the wire. The electrical current produces a magnetic core.
- Commutator—a switch that changes the direction of the electric current flowing through the armature of an electromagnet.

## Equipment/Supplies

- Medicine dropper with bulb removed
- Stick of modeling clay
- Two bar magnets
- Three16d nails
- Four 4d nails
- Insulated bell wire
- Roll of electrician's tape
- Two pieces of corrugated cardboard
- Aluminum sheet material
- Piece of 1/4"x6"x8" plywood
- Batteries (one 6-volt or four 1.5-volt dry cells)

---

## Introduction

It is estimated that about 60 percent of the electrical energy consumed in the United States is used to operate electric motors. Electric motors are an important part of our daily lives because they affect or operate a great many of the things we use on a daily basis, from ceiling fans in homes to computers at school.

Electrical motors operate mainly because of the characteristics of magnets. As you well know, magnets with unlike poles attract each other, and magnets with like poles repel each other. A magnetic piece of metal differs from a nonmagnetic piece of metal in the arrangement of the electrons contained in the metal. A nonmagnetic piece of metal has its electrons randomly arranged with no particular order about them. In a magnet these electrons are lined up in what is called a *spin* of electrons. This orderly spin of electrons is what creates a magnetic field. The more electrons contained in the spin, the stronger the magnet.

A magnet has an effect on the area around it. This area is called the magnetic field and consists of lines of flux. These lines begin inside the magnet and curve around to the opposite end of the magnet. Lines of flux do not cross but are able to penetrate nonmetallic material and follow other magnetic materials. The more lines of flux present in a magnetic field, the stronger the magnet.

Electromagnetism is what causes an electric motor to operate. When an electrical current passes through a wire, a small amount of magnetism is created around the wire. When a wire is wrapped into a coil, this magnetic field becomes stronger. As the number of turns of wire and the amount of current flowing through the wire increases, the magnetism also increases. If a soft iron rod is placed in the center of these coils, the lines of flux will form through the center of the coils, creating a magnet with well-defined north and south poles. Soft iron is used in electrical motors because it loses the magnetism rather quickly after the electrical current has been cut off.

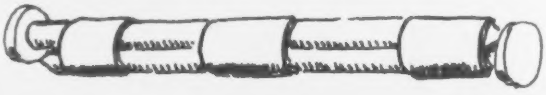
An electric motor is made to operate by the attracting and repelling action of electromagnets. Remember that if a magnet is placed near another magnet with the opposite pole, the two magnets will be drawn together. If, however, the poles are the same, they will tend to repel each other. An electrical motor operates because one of the magnets is stationary and the other is placed around a rotating shaft. These two electromagnets are the basis of the electric motor.

The other important component of the motor is the commutator. The commutator is like a rotary switch which is necessary to make the two electromagnets turn the motor's shaft. The rotor inside the motor is what is made to turn by the push and pull of the electromagnets. The commutator is attached to the rotor, and the brushes on the frame of the motor touch the commutator and cause an electrical current to activate the electromagnet, which pulls the rotor towards the stationary magnet. As the rotor is pulled toward the stationary magnet, also known as the stator, the brush and the commutator lose contact, and the magnetic attraction is temporarily stopped. A different brush and commutator connection occurs and keeps the rotation of the shaft going in the same direction. This is the basis of all electrical motors. The number of poles in the motor, the number of windings, the amount of current, etc., all vary from one motor type to another, but they all work basically the same.

**Procedure**

In order to help you better understand the theory of electromagnetism and the operation of an electric motor, you are asked to complete the following activity.

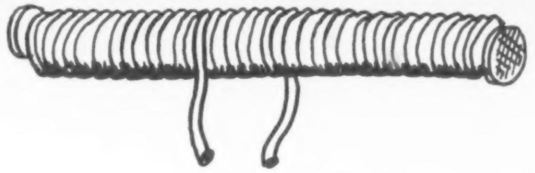
1. Divide up into groups of three or four students, and secure the necessary materials from your instructor.
2. Tape two 16d nails together as shown below.



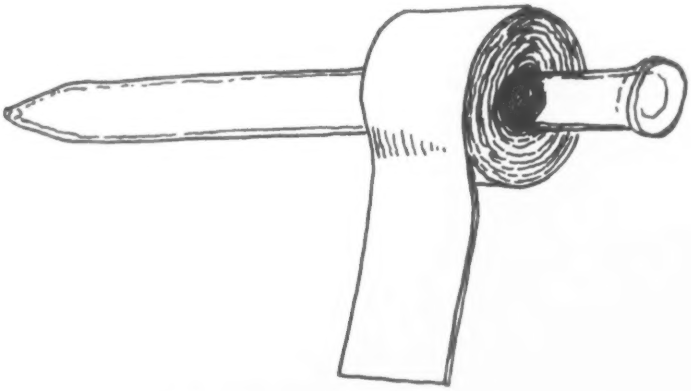
STEP 2: TAPE 2 NAILS TOGETHER

3. Make the armature of the motor by winding your bell wire around the nails. Start winding at the center, and carefully wind to the end of the nail and then back towards the center. Be careful to wind in the same direction. When you

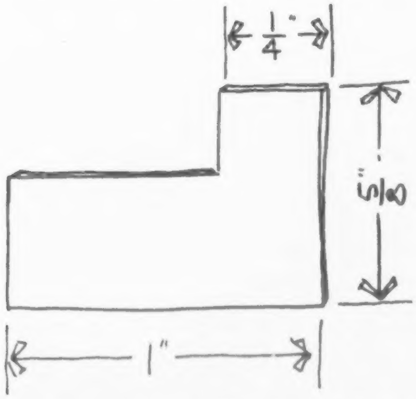
have wound the coils back towards the center of the nail, leave about 1" of wire extending toward the bottom.



4. Take your medicine dropper and remove the rubber bulb. Be careful not to crack the glass dropper. Wrap the electrical tape around the glass dropper about 1/2" from the open end. Wrap enough tape to form a diameter of about 1/2".

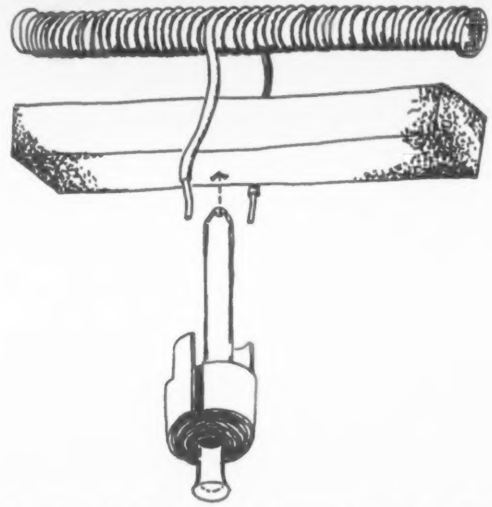


5. Cut two pieces of thin copper sheet into the L-shape as shown below. Form them around the taped cylinder, and trim them so that they fit neatly but do not touch. There should be a narrow gap between each piece. They cannot touch. Neatly secure them to the wrapped tape with small pieces of tape on the top and the bottom. Check to make sure there is a small gap between them.

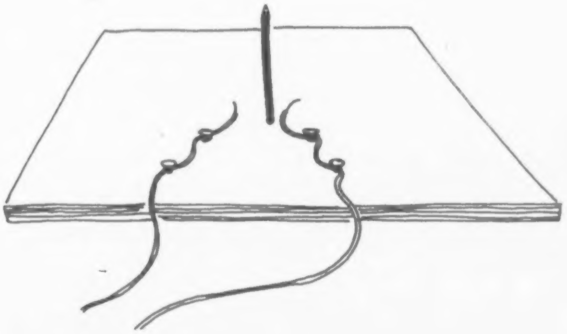


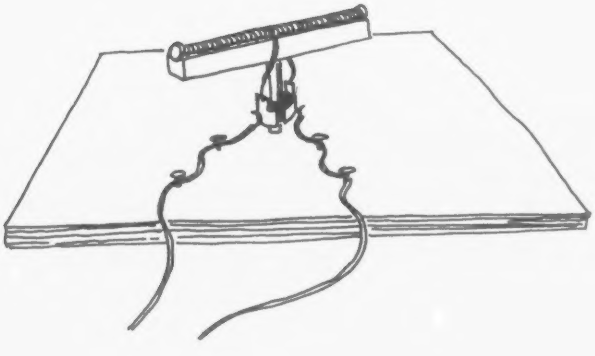
6. Push the electromagnet into the top of the bar of modeling clay, and run the two loose wires towards the bottom. On the underside of the bar of clay, locate the exact center, and carefully push the pointed end of the dropper into

the clay. The weight of the clay will help as a kind of flywheel. Solder the two leads from the electromagnet to the two pieces of copper. This device forms the commutator of the electric motor.

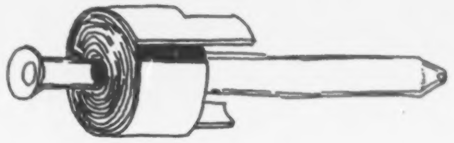


7. Drill a small pilot hole through the center of your plywood base, and drive a 16d nail through this hole. Keep the nail as straight as possible. Drive four small nails into the base as shown below.

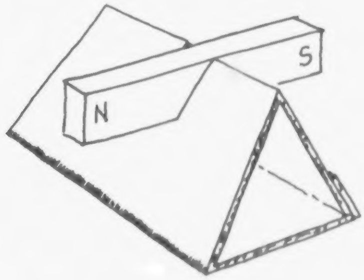


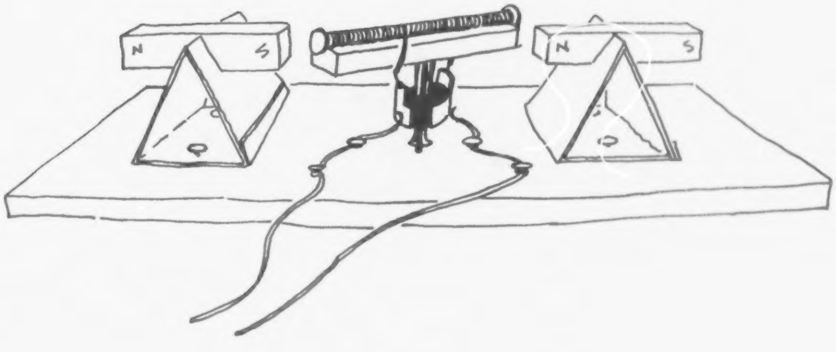


8. Place the commutator over the 16d nail as shown below, and form the motor brushes by stripping about 1/2" of insulation from the ends. Form the brushes as shown in the diagram below.



9. Form the bar magnet holders from the cardboard as shown below. Cut a slit in the top edge deep enough so that the bar magnets will be directly in-line with the electromagnet. Once you have determined where their exact location needs to be, then use thumb tacks to secure these holders to the plywood base.





10. Connect the motor to the battery, and spin the electromagnet slightly to get your motor started. You may need to make minor adjustments in connections and locations to make it work.
11. After your group has successfully operated the motor, your instructor will ask you to participate in a discussion of the project.

12. Make the following observations:
    a. What form of energy is present in the spinning armature?
    b. List five forms of energy present in the moving electrical motor assembly.
    c. Stop the motor after it has run for a while, and feel the coils. What form of energy has been created in the coils?

## Evaluation

Evaluation of your performance will be based on your participation in and completion of the activity.

# USING A VOLT-OHM-MILLIAMMETER (VOM) TO MEASURE VOLTAGE

---

**Essential Elements:** Common: 2, 6, 8, 9, 10
Specific: 1
**TAAS Objectives:** Language Arts: RC 1-6

---

## Activity Summary

This activity is intended to introduce students to the use of a voltmeter to measure voltage in a DC circuit. Students will use a typical volt-ohm-milliammeter (VOM) to make their measurements.

## Teaching Tips

1. Read through the entire activity before releasing it to students.
2. Cover use of equipment before allowing students to use instruments.
3. Review safety procedures as necessary.

## Instructional Strategy

- Use the activity as either a small group or individual project as necessary.
- Lecture to present the topic to students.
- Demonstrate the proper use of the instrument.

## Equipment/Supplies

1. VOM analog meter
2. Set of leads with alligator clips
3. Three 1.5V dry cell batteries
4. Circuit board
5. Spring clips or terminals
6. Knife switch
7. 6V lamps (No. 44)
8. Length of #18 or #20 insulated copper wire

## Evaluation Key

Instructor evaluation of student performance should be based on participation in and completion of the activity.

# USING A VOLT-OHM-MILLIAMMETER (VOM) TO MEASURE VOLTAGE

*Learn how to use a voltmeter to measure voltage in a DC circuit.*

---

## Objective

- To use a VOM correctly

## Vocabulary/Concepts Reinforced

- Analog—a measurement instrument where the reading is taken from numbers on a scale, and the indicator is made by a needle or pointer across the scale.
- Digital—a measurement instrument where the reading is displayed numerically with range selection and decimal point placing accomplished automatically.
- Meter rectifier—because the VOM is basically a DC instrument, a built-in device known as a rectifier converts AC current to DC current.
- Multiplier resistor—to convert the VOM into a voltmeter a resistor is placed in series with the meter circuit. The value of the resistor is calculated so that it will limit the meter current to the full-scale deflection value at the highest voltage that the meter is designed to measure.
- Shunt resistor—in a multimeter, a shunt resistor is added in parallel with the meter circuit to prevent damage to the coil. The shunt is wired so that the meter will only carry part of the current.
- VOM—a volt-ohm-milliammeter (VOM, or multimeter) is a multirange instrument capable of switching to change both shunts and multiplier resistors to measure many different ranges of voltage, current, and resistance with the same meter.

## Equipment/Supplies

- VOM analog meter
- Set of leads with alligator clips
- Three 1.5V dry cell batteries
- Circuit board
- Spring clips
- Knife switch
- 6V lamp (No. 44)
- 3-foot length of #18 or #20 insulated copper wire

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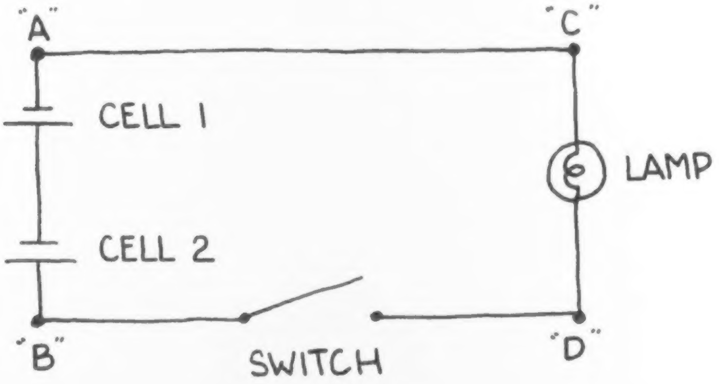
## Introduction

One of the fundamental instruments that will be used in all phases of electrical and electronic work is the volt-ohm-milliammeter (VOM). The VOM, or *multimeter,* is used to measure many different ranges of voltage, current, and resistance. The multimeter is capable of measuring voltage rise from an electrical source such as a battery or a generator or a voltage drop across a device that uses electrical current.

In order to measure voltage rise or drop, the meter must be placed in parallel with the circuit. It is important to observe the polarity in DC circuits to prevent damage to the needle. Also, be sure to set the range-selector switch to the proper voltage range. Whenever you are not certain about the voltage range to be measured, start with the highest range scale, and adjust downward as necessary. Also, do not hold on to the meter leads when taking readings on high-voltage circuits. Instead, clip the leads in place with the circuit or device de-energized.

**Procedure**

1. Set up the multimeter for use as a voltmeter.
   a. Turn the function switch to the +DC position.
   b. Turn the selector switch to the 10V scale.
   c. Attach the alligator clips to the meter test leads (red to red, black to black).
   d. Place the red meter lead into the positive jack and the black meter lead into the negative or common jack.
2. Wire three 1.5V batteries in series, and measure their voltage. Make a note of the voltmeter reading (it should be about 4.5V).
3. Reconnect the same three batteries in parallel and measure the voltage again. Note the voltage. It should be about the same as one of the batteries, 1.5V.
4. Connect two of the 1.5V batteries in series again. This time, however, wire them so that they are in opposition to each other. If you have made your connections correctly, the voltage reading should be 0V.
5. Set up the simple circuit shown below, using materials from your instructor.



   a. Set the range selector to the 10V scale.
   b. Touch the red probe to terminal "B," and hold the probe by the sleeve.
   c. Touch the black probe to terminal "A," and record the voltage:________________
   d. Now touch the black probe to terminal "C," and check the voltage between terminals "B" and "C":________________
   e. Place the black probe to the negative terminal of the second dry cell, and record the voltage: ________________
   f. Measure the voltage between the negative terminal of the second dry cell and terminal "A": ________________
   g. Close the switch in the circuit, and measure the voltage between terminals "C" and "D": ________________
   h. With the switch closed, measure the voltage between terminals "D" and "B": ________________
   i. Where does the voltage drop? ________________

6. Discuss your findings in a class discussion of the activity.

**Evaluation**

Evaluation of your performance will be based on participation in and completion of the activity.

ELECTRICITY/ELECTRONICS SYSTEMS
INSTRUCTOR'S RESOURCE SHEET 27
(1 DAY)

## READING AN ELECTRIC METER

---

**Essential Elements:** Common: 2, 6-9
Specific: 1, 5
**TAAS Objectives:** Language Arts: WC 1-6

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### Activity Summary

This activity is intended to address the power generation and distribution of electricity by public utilities. In this activity students will learn how to read a standard electric meter.

### Teaching Tips

1. Have a guest speaker from the local electrical company talk to your students about electrical distribution and consumption.
2. Bring in samples of electrical bills to discuss how the electrical company bills customers for electricity.
3. Create a bulletin board display on the topic.
4. Make a model of the electrical meter dials for use on the overhead transparency machine.

### Instructional Strategy

- Lecture to present the topic to students.
- Use this activity as an individual project.
- Use a summary group discussion to talk about individual student findings.

### Equipment/Supplies

Copies of student worksheet

### Eavaluation Key

Instructor evaluation of student performance should be based on participation in and completion of the activity.

# READING AN ELECTRIC METER

*Learn how to read a standard electric meter.*

---

## Objectives

- To develop an understanding of the distribution and sale of electrical energy
- To learn to read an electrical meter
- To develop an understanding of energy use patterns

## Vocabulary/Concepts Reinforced

- Watt-hour—the amount of watts consumed in one hour; for example, a 150-watt light bulb will use 300 watt-hours in two hours.
- Kilowatt-hour—the prefix "kilo" means 1,000. In an electrical device such as a 100-watt light bulb, it represents the amount of electricity consumed by the bulb in 10 hours.
- Electric meter—the standard electric meter is the device used by electrical distribution companies to measure the amount of electrical energy consumed by their customers. Most electric meters measure the number of kilowatt-hours used by reading a series of dials on the meter.

## Equipment/Supplies

- None

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## Introduction

Electrical energy is one of our most important commodities. Almost all Americans have grown accustomed to the conveniences of electrical energy and probably enjoy the most economical electricity in the world. Consumption of electrical energy is, however, a serious issue. Everyone should learn to conserve electricity, if not for the good management of energy, at least for its economy.

Standard electrical appliances or devices use electrical energy to perform their various tasks. The electrical energy used is measured in units called watts. If we burn a 75-watt light bulb for one hour, it will have consumed 75 watt-hours of electricity. If that same bulb is burned for 10 hours, it will have consumed 750 watt-hours. Most electricity is sold to customers by the kilowatt-hour. This means that a 100-watt light bulb burning for 10 hours will consume 1 kilowatt-hour of electricity.

## Procedure

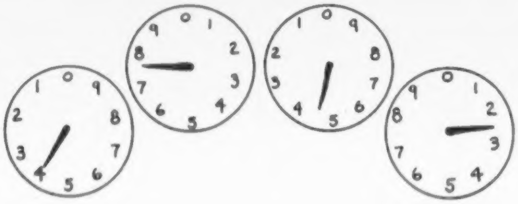
In order to better understand how an electric meter operates, complete the following worksheet.

## Evaluation

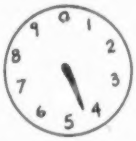
Instructor evaluation of your performance will be based on participation in and completion of the activity.

## Student Worksheet 1

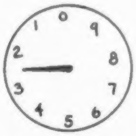
Study the diagrams below, and complete the questions for each section.



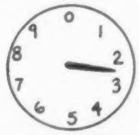
1. When reading a meter dial it is important to understand what the meter is indicating. In a typical meter the dial will often be pointing at a space between numbers. If you see this, the meter should be read for the lower number. Study the dial below. It is indicating the number 4.



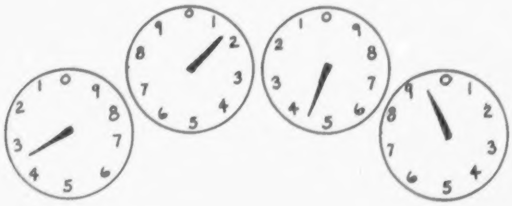
2. Study the dial below. What is the correct dial reading? ________



3. Study the dial below. What is the correct dial reading? ________

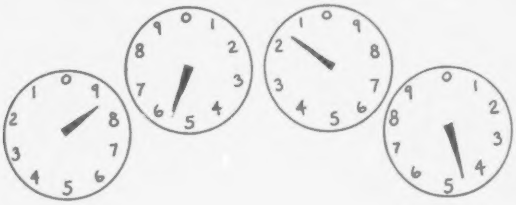


4. Most meters have a row of four or five dials. Note in the diagram below that every other dial goes around a different direction. Some are read clockwise, while others are read counterclockwise. It does not matter how the meter turns—you should always read the smaller of the two numbers. For the diagram below, write down the meter reading from left to right.



______ ________ ________ ______

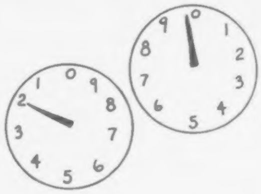
5. Study the meter dials below, and write down the correct meter reading.



1 0 9
2 8
3 7
4 5 6
9 0 1
8 2
7 3
6 5 4
1 0 9
2 8
3 7
4 5 6
9 0 1
8 2
7 3
6 5 4

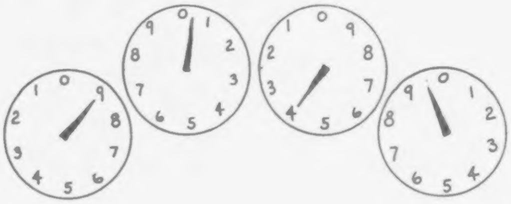
_____ _____ _____ _____

Sometimes a dial may be pointing at a number, but it is not clear whether it is exactly on the number. Study the diagram below. Note how the dial on the left almost appears to be pointing at the 2. Now look at the next dial to the right. It has not quite gone past the 0. In this situation, the dial reading should be 1. If the second had gone past the 0 towards 1, the first dial would then read 2.



1 0 9
2 8
3 7
4 5 6
9 0 1
8 2
7 3
6 5 4

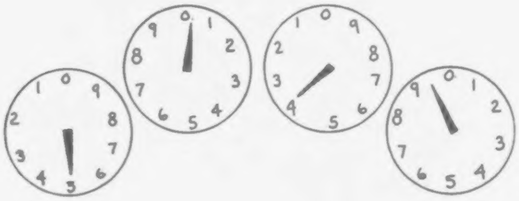
6. Study the diagram below and indicate its reading.



1 0 9
2 8
3 7
4 5 6
9 0 1
8 2
7 3
6 5 4
1 0 9
2 8
3 7
4 5 6
9 0 1
8 2
7 3
6 5 4

_____ _____ _____ _____

7. Study the diagram below and indicate its reading.



1 0 9
2 8
3 7
4 5 6
9 0 1
8 2
7 3
6 5 4
1 0 9
2 8
3 7
4 5 6
9 0 1
8 2
7 3
6 5 4

_____ _____ _____ _____

# KEEPING AN ELECTRICAL USE LOG

| | |
|---|---|
| **Essential Elements:** | Common: 6-9<br>Specific: 1, 5 |
| **TAAS Objectives:** | Language Arts: WC 1-6 |

## Activity Summary

This activity is intended to provide students with an opportunity to observe their families' consumption of electrical energy. The activity centers around two student worksheets. In the first worksheet, students keep a one-day log of their home electrical usage. In the second worksheet, students keep a week-long log of their home electrical usage and plot the data on a bar graph.

## Teaching Tips

1. Use this activity after students have completed Activity 27 on reading an electrical meter.
2. Talk to your students about the importance of energy conservation, and encourage them to make careful observations for this activity.
3. You may want to plot all of the collected data on one larger graph for the entire class.
4. Create a bulletin board display for the entire school to view.

## Instructional Strategy

- Lecture to present the topic to students.
- Use this activity as an individual student project.
- Have a class discussion of student findings upon completion of the activity.

## Equipment/Supplies

Copies of student worksheets

## Evaluation Key

Instructor evaluation of student performance on this activity is based on participation in and completion of the project.

# KEEPING AN ELECTRICAL USE LOG

*Observe and record your family's consumption of electrical energy.*

## Objectives

- To understand the importance of energy conservation by observing typical family usage of electricity.
- To collect data and plot that information on a record sheet
- To be able to describe how electrical utility companies measure electrical energy consumption for billing purposes

## Vocabulary/Concepts Reinforced

- Kilowatt-hour—a measure of electrical energy used by an appliance or a device. A kilowatt-hour represents how many thousands of kilowatts are used in one hour of operation. A 100-watt light bulb will use one kilowatt of electricity in 10 hours.

## Equipment/Supplies

- None

## Introduction

Now that you know how to read an electrical meter, it is interesting and fun to apply this knowledge to observe how much electrical energy your family consumes. Electrical usage is something that many of us take for granted. We flip a switch, the TV turns on, and we never really think about the set actually consuming electricity or how much it costs. How many times do we walk out of a room and leave a light turned on? Thinking about electricity consumption is important, and being conscious of electrical usage is a good habit to develop.

## Procedure

In this activity, you will apply your electrical meter reading skills to observe and plot electrical usage. In the first worksheet, you will plot the electrical usage during a one-day period, recording the data on a chart, and then plotting that information on a bar graph. It is important to try to pick a typical weekday, although a weekend day will be satisfactory.

In the second activity, you will record electrical usage over a period of one week. Again you will take meter readings and record electrical consumption on a daily basis. At the end of the recording period, you will plot your data on a bar graph.

## Evaluation

Instructor evaluation will be based on completion of two student worksheets and participation in the class discussion of the topic.

# ONE DAY ELECTRICITY USE LOG

DAY OF THE WEEK: ______________

READINGS

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CONSUMPTION

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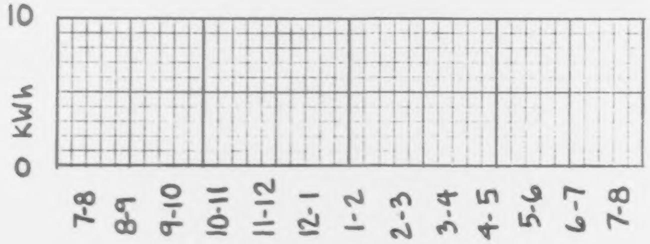
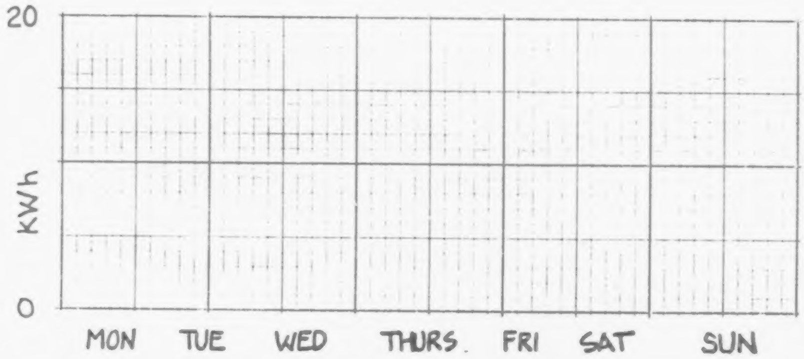


USE THIS CHART TO PLOT DAILY ELECTRICAL CONSUMPTION

## ONE WEEK ELECTRICITY USE LOG

| DAY OF WEEK | TIME OF READING | READING | KWh USED LAST 24 HRS |
|---|---|---|---|
| SUNDAY | | | |
| MONDAY | | | |
| TUESDAY | | | |
| WEDNESDAY | | | |
| THURSDAY | | | |
| FRIDAY | | | |
| SATURDAY | | | |
| SUNDAY | | | |



USE THIS GRAPH TO PLOT YOUR WEEKLY ELECTRICAL CONSUMPTION.

ELECTRICITY/ELECTRONICS SYSTEMS
INSTRUCTOR'S RESOURCE SHEET 29
(1-3 DAYS)

## INTRODUCTION TO SEMICONDUCTORS

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| | |
|---|---|
| **Essential Elements:** | Common: 7, 8, 9<br>Specific: 10 |
| **TAAS Objectives:** | Language Arts: RC 1-6 |

---

### Activity Summary

This activity is intended to provide students with a general understanding of semiconductors and their place within the field of electronics.

### Teaching Tips

1. Read through the activity and become familiar with it before releasing it to students.
2. Explain the internal atomic structure of the semiconductor device.
3. Explain how a transistor works.
4. Discuss the op-amp and its circuitry.
5. Discuss integrated circuits in general.

### Instructional Strategy

- Lecture to present the topic to students.
- Use this activity as an individual study project.
- Use the student worksheet to check for understanding.

### Equipment/Supplies

Copies of student worksheet

### Evaluation Key

Instructor evaluation of student performance will be based on completion of the student worksheet.

1. four
2. impurities
3. N-type
4. conventional
5. current
6. beta
7. FET
8. out of
9. 10
10. 12

# INTRODUCTION TO SEMICONDUCTORS

*Study semiconductors and their place within the field of electronics.*

---

## Objective

- To develop a general understanding of semiconductors and their place within the field of electronics

## Vocabulary/Concepts Reinforced

- Diode
- Field effect transistor
- Integrated circuit
- Operational amplifier (op-amp)
- Voltage divider

## Equipment/Supplies

- None

---

## Introduction

In the study of electronics, one of the most important areas covers semiconductors. Basically, a semiconductor is a material that conducts electricity. Semiconductor devices include diodes, lamps, lasers, radiation detectors, solar batteries, and transistors.

The silicon atom, which has 14 protons and a total of 14 electrons, has an outer orbit of 4 electrons. The outer orbit, which is called the valence orbit, is where all the action is. Modern physics describes the orbits of the atom as having energy levels which are fixed for each orbit. External energy such as light or heat can increase the energy level of an electron and cause it to move to a higher orbit. When the energy source is removed, the electron can fall back into its initial orbit and in the process give off light and heat energy. For the silicon atom to be chemically stable, it needs to have a total of 8 electrons in the outer orbit. That is, it has to combine its 4 electrons with another atom's 4 electrons. This pattern will result in a stable crystalline structure which is an insulator. To make the silicon into a semiconductor, impurities are added that have outer orbits with either 5 or 3 electrons. This results in silicon with either an excess of electrons, which is called N-type, or a deficiency of electrons, called P-type.

The simplest active device is the diode, which is made by putting N-type material together with P-type material. This results in a device that allows current to flow only one way and requires 0.7 volt of energy to overcome the depletion area, which is the point where the N-type and P-type material are bonded together. To make a transistor, additional material is added to make either an NPN or PNP device.

The transistor which is made by sandwiching N-type with P-type and then N-type material is called bipolar because of the two types of material with different polarity. The NPN and PNP transistors operate the same except for the different polarity.

There are two ways of looking at the direction in which current flows, either conventional current flow or electron current flow. Electron flow is the actual direction in which electrons flow, which is from negative to positive. However, when electronics was still in its infancy, nobody knew in which direction current flowed and they guessed wrong. Conventional current flow, which comes from this wrong guess, says current flows from positive to negative. Today, most engineers and technicians use conventional current flow because it is easier to deal with positive numbers and everything comes out the same anyway. In this discussion, we will use conventional current flow except where we specifically discuss the electrons and what they are doing.

Figure 1 is a diagram of an NPN-type transistor. Using conventional current flow, the arrows indicate that current flows into the P region in the center, which is called the *base*, and also into the N region on top, which is called the *collector*. Both the base current and the collector current flow out the bottom N-type material, which is called the *emitter*. The transistor can be described as a current-controlled device unlike the tube which it has replaced which was a voltage-controlled device. For a transistor, the controlling current comes in the base, or the collector current is controlled by the amount of base current. Figure 2 show the schematic symbol for a transistor with the base and collector currents labeled. The most common transistors will have a ratio of collector current to base current of from 75 to about 400. Most technicians will assume a ratio of 100 to 1 when working with transistors if they don't know the specific value. This ratio is called *beta*.

The usual way to design a transistor circuit is to provide a constant level of base current with a solid voltage divider connected to the base and a collector resistor, which provides the load to work against, and an emitter resistor, which will lower the gain and provide stability.

Figure 3 shows the schematic diagram for a transistor circuit. $R_1$ and $R_2$ provide the voltage divider to supply a constant level of base current which is called the bias. When a signal comes into the base, the variations of the signal will cause the base current to fluctuate, which will cause fluctuations in the collector current. The amount of actual voltage gain this circuit has is approximately equal to the ratio of the collector resistor divided by the emitter resistor. If we put a capacitor from the emitter of the transistor to ground and bypass the emitter resistor, we can increase the voltage gain up to as much as 200.

There are other types of transistors called unipolar, which means just one type of material, either P or N. The JFET, or junction field effect transistor, is a voltage-controlled device that takes very little current into the input or has a high input impedance. There is also the MOS family of field effect transistors, which stands for metal oxide semiconductor. This family is composed of CMOS, NMOS, and PMOS transistors. Most of these are used in integrated circuits for computers.

Integrated circuits, or ICs, are transistor circuits built on a single piece of silicon and encapsulated in plastic. The most common linear IC is the operational amplifier, or op-amp.

Figure 4 show the schematic diagram for an op-amp. The op-amp has a double input feeding a differential amplifier. The plus and minus signs indicate the phase relationship between the input and the output. A minus sign indicates that the output will be 180 degrees out of phase with a signal coming into that input. The voltage gain in a typical op-amp is very high, around 100,000. This is too much

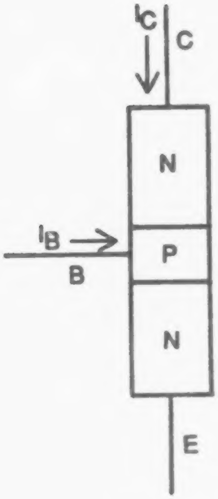
$I_C$
C
N
$I_B$
B
P
N
E

Figure 1

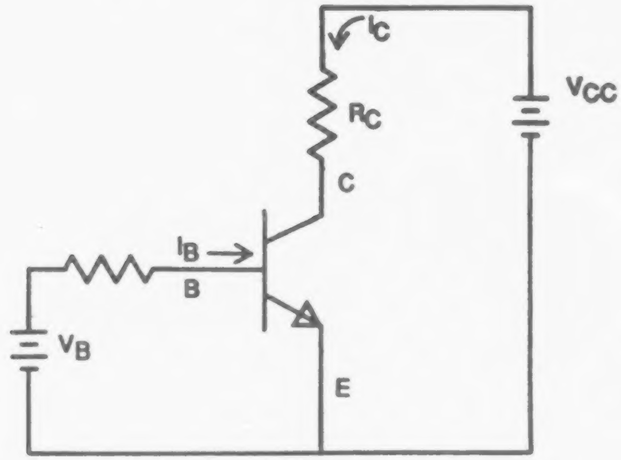
$I_C$
$V_{CC}$
$R_C$
C
$I_B$
B
$V_B$
E

Figure 2

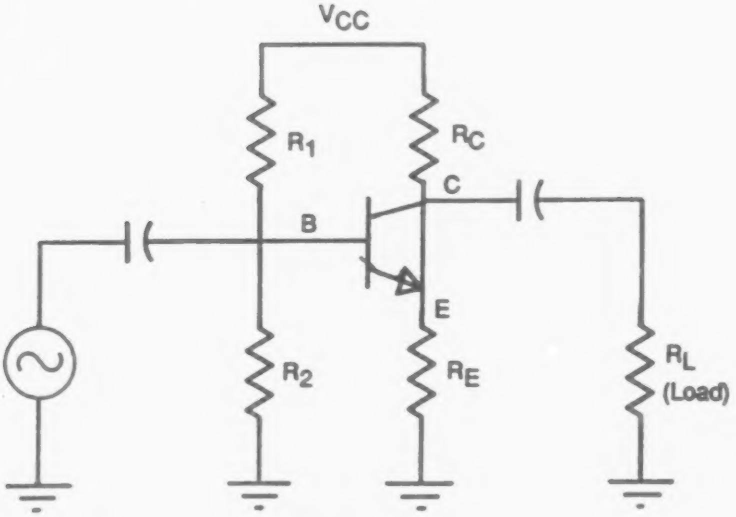
$V_{CC}$
$R_1$
$R_C$
C
B
E
$R_2$
$R_E$
$R_L$
(Load)

Figure 3

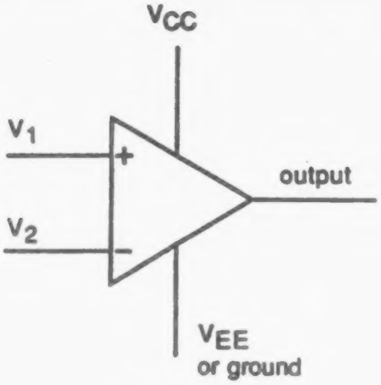
VCC
V1
+
output
V2
−
VEE
or ground

Figure 4

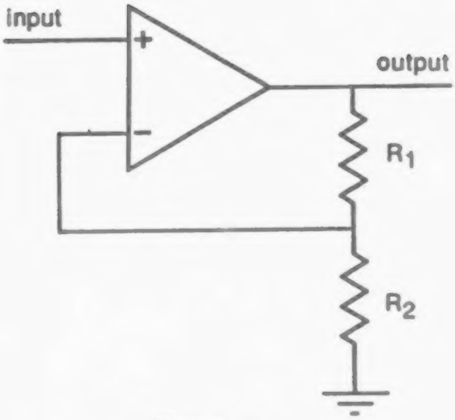
input
+
output
−
R1
R2

Figure 5

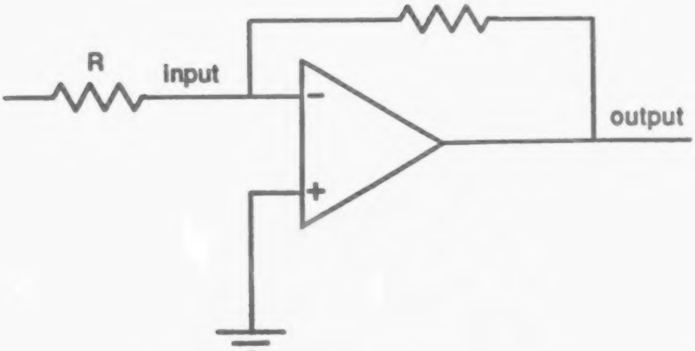
RF
R
input
−
output
+

Figure 6

gain for any normal linear function. The input impedance for a typical op-amp is high, and the output impedance is low. The maximum frequency that an op-amp can amplify is generally not very high. The 741 op-amp can go as high as one megahertz for unity gain or no gain at all. Higher voltage gains will require a lower frequency. The reason for this is a capacitor inside the device which is necessary to stabilize the op-amp.

A practical circuit is shown in figures 4 and 5. Figure 4 shows a voltage divider. Resistors $R_1/R_2$ (fig. 5) will lower the gain and stabilize the operation of the op-amp. The gain of this circuit is equal to $R_1/R_2$, plus 1. Since the input goes into the plus input or noninverting input, the output is in phase with the input. This circuit also increases the input impedance and lowers the output impedance. Distortion developed within the device is also reduced. In figure 4, we show a line for the positive voltage supply and a line for the negative voltage or ground supply; however, it is customary to leave those lines off when drawing a complete circuit. You are expected to know that you will have to supply power to the device. Figure 6 shows a circuit using an op-amp that has the output out of phase with the input. Often this circuit is built with just the $R_F$ resistor, and the R is the output impedance of the circuit driving it. The voltage gain for this circuit is $R_F$ divided by R. This can be a very simple circuit to build and use. Many technicians use this circuit frequently to solve the need for additional gain when trying to install a difficult circuit board into a piece of equipment.

The op-amp can be looked at as a basic building block in a circuit. There are many other linear ICs which are designed for specific purposes. For example, Exar manufactures an IC called "Speakerphone Control IC." It includes almost all of the circuitry necessary to operate the speakerphone function on a telephone. This chip or IC has circuitry in it to reduce the feedback from the speaker to the microphone and to switch automatically from talk to listen. Major portions of radio and television circuitry have been put into single ICs, and today there is a move toward custom designing ICs, for specific applications for one manufacturer. Using ICs in a piece of equipment will reduce the cost to manufacture it and increase the reliability of the equipment. The reliability of modern electronic equipment has become very good.

**Procedure**
Complete the following worksheet.

### Student Worksheet—Semiconductors

1. The silicon atom has _____________ atoms in its outer orbit.

2. To turn silicon into a semiconductor, ___________ must be added to the silicon.

3. A deficiency of electrons in the semiconductor is called _______________ material.

4. _____________ current flow flows from positive to negative.

5. A transistor is a _____________________ controlled device.

6. The ratio of current between the collector and the base of a transistor is called the __________________.

7. The voltage-controlled transistor is called ________________.

8. The minus sign on the input of an op-amp indicates that the output will be ______________ phase with the input.

9. An op-amp circuit with the voltage divider circuitry has $R_1$ equal to 9 kΩ and $R_2$ equal to 1 kΩ. The gain of this circuit is _________.

10. An op-amp circuit that has the input out of phase with the output is being fed from a circuit with 1 kΩ output impedance. Resistor $R_F$ is 12 kΩ. The voltage gain of the circuit is __________.

**Evaluation**

Instructor evaluation will be based on participation in and completion of the student worksheet.

(2 DAYS)

# RESISTOR COLOR CODE/OHMMETER FAMILIARIZATION

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**Essential Elements:** Common: 6A, 6B, 8C, 9A, 9B
Specific: 9
**TAAS Objectives:** Mathematics: C 1, 2, 4; O 2, 3
Language Arts: RC 4, 5; WC 1

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## Activity Summary

This activity is designed to give students the opportunity to calculate the resistance value of carbon composition resistors using the Resistor Color Code. Students will also be given the opportunity to measure the resistance value of carbon composition resistors using the ohmmeter function of a multimeter.

## Teaching Tips

1. Read through the activity before beginning.
2. Reproduce activity sheets for each student, or lab group, before the activity.
3. Organize all equipment and supplies before the activity.

## Instructional Strategy

- Explain and demonstrate the construction and use of carbon composition resistors.
- Introduce the schematic symbol used to represent a carbon composition resistor.
- Demonstrate the use of the Resistor Color Code to identify the resistance values of carbon composition resistors.
- Demonstrate the use of the ohmmeter function of a multimeter to measure the resistance values of carbon composition resistors.

## Equipment/Supplies

1. 1/2-watt carbon composition resistors of various resistance and tolerance values
2. Analog, or digital, multimeter

## Evaluation Key

1. Instructor evaluation of student's ability to interpret Resistor Color Code information on each resistor.
2. Instructor evaluation of student's ability to measure the resistance value of each resistor using the ohmmeter function of a multimeter.
3. Instructor evaluation of student's ability to follow the procedures of the activity sheet.

# RESISTOR COLOR CODE/OHMMETER FAMILIARIZATION

*Experiment with carbon composition resistors and the ohmmeter.*

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## Objectives

- To identify the resistance value of carbon composition resistors using the Resistor Color Code
- To read resistance values of carbon composition resistors using the ohmmeter function of a multimeter
- To identify the difference between the calculated resistance value and the measured resistance value of a carbon composition resistor

## Vocabulary/Concepts Reinforced

- Resistance
- Resistor
- Resistor Color Code
- Tolerance
- Ohmmeter
- Multimeter

## Equipment/Supplies

- 1/2-watt carbon composition resistors of various resistance and tolerance values
- Analog, or digital, multimeter

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## Introduction

Resistors are commonly used devices in electrical and electronic circuits. Carbon composition resistors are placed in many circuits to reduce voltage values and limit current flow. Carbon composition resistors contain a carbon-based mixture used to produce a specific amount of resistance to current flow. Carbon composition resistors are small, easily manufactured, inexpensive, and have a limited wattage range. Carbon composition resistors are rated by their wattage and resistance values.

The physical size of a resistor indicates the wattage capacity of the carbon composition resistor. Carbon composition resistors have a wattage range between 1/16 watt and 2 watts.

A knowledge of the use of the Resistor Color Code is essential to the identification of the resistance values of carbon composition resistors. Four color bands are placed on a carbon composition resistor to indicate the resistance value of the resistor. The first color band indicates the first digit of the resistance value. The second color band indicates the second digit of the resistance value. The third color indicates the multiplier value of the resistor. The fourth color band indicates the tolerance range of the resistor.

The table that follows may be used to determine the value of a resistor.

## RESISTOR COLOR CODE TABLE

| Color Bands | Numerical Value 1st Digit | Numerical Value 2nd Digit | Decimal Multiplier | Tolerance Percentage |
|---|---|---|---|---|
| black | --- | 0 | 1 | 1% |
| brown | 1 | 1 | 10 | 2% |
| red | 2 | 2 | 100 | |
| orange | 3 | 3 | 1,000 | |
| yellow | 4 | 4 | 10,000 | |
| green | 5 | 5 | 100,000 | |
| blue | 6 | 6 | 1,000,000 | |
| violet | 7 | 7 | 10,000,000 | |
| gray | 8 | 8 | 100,000,000 | |
| white | 9 | 9 | 1,000,000,000 | |
| silver | --- | --- | 0.01 | 10% |
| gold | --- | --- | 0.1 | 5% |
| none | --- | --- | --- | 20% |

As an example of the Resistor Color Code, a resistor with the color bands brown, green, red, and silver will have a resistance value of 1,500 ohms with a + or - 10% tolerance range.

The resistance value of a carbon composition resistor can be measured by an ohmmeter. The use of an ohmmeter is also a basic function of any person working with electrical or electronic circuits. An ohmmeter function is common to any multimeter; it is used to measure DC resistance of a component or a circuit. Many electrical and electronic components can be tested with the ohmmeter.

The ohmmeter uses its own power source to supply voltage to the component being tested. Circuit power should be turned off when measuring resistance values with an ohmmeter to eliminate any interference from the power source of the circuit. To measure the resistance value of a carbon composition resistor, the ohmmeter is set to the proper resistance range and the probes of the ohmmeter are placed across the terminals of the resistor.

### Procedure

1. Select eight 1/2-watt carbon composition resistors with different color bands.
2. List the color bands, resistance value, and tolerance range for each resistor in the blanks of the chart below.

| R | 1st color band | 2nd color band | 3rd color band | 4th color band | resistance value | tolerance range |
|---|---|---|---|---|---|---|
| 1 | | | | | | |
| 2 | | | | | | |
| 3 | | | | | | |

| | | | | | | |
|---|---|---|---|---|---|---|
| 4 | | | | | | |
| 5 | | | | | | |
| 6 | | | | | | |
| 7 | | | | | | |
| 8 | | | | | | |
| | | | | | | |

3. Set the multimeter to the proper ohmmeter range to measure the resistance value of each resistor.

$R_1$= ________________ ohms

$R_1$= ________________ ohms

$R_2$= ________________ ohms

$R_3$= ________________ ohms

$R_4$= ________________ ohms

$R_5$= ________________ ohms

$R_6$= ________________ ohms

$R_7$= ________________ ohms

$R_8$= ________________ ohms

4. Indicate the difference between the calculated resistance value of each resistor in **Step 2** and the measured value of each resistor in **Step 3** in the chart below.

| R | calculated resistance value | measured resistance value | difference |
|---|---|---|---|
| 1 | | | |
| 2 | | | |
| 3 | | | |
| 4 | | | |
| 5 | | | |
| 6 | | | |
| 7 | | | |
| 8 | | | |

5. Does the tolerance range of the resistors have an effect on the difference between the calculated and the measured resistance values of the resistors? Why could it have an effect on the differences?

6. Return the resistors to their original location, and turn the multimeter dial to the "off" position.

**Evaluation**

Evaluation is based on your ability to calculate and measure the resistance values of carbon composition resistors by following the procedure steps of the activity.

(2 DAYS)

# AC-DC WAVEFORM/OSCILLOSCOPE FAMILIARIZATION

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| | |
|---|---|
| **Essential Elements:** | Common: 6A, 6B, 8C, 9A, 9B<br>Specific: 1, 2, 8 |
| **TAAS Objectives:** | Mathematics: C 1, 4<br>Language Arts: RC 4, 5; WC 1 |

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## Activity Summary

This activity is designed to provide students with the opportunity to investigate the difference between alternating and direct current waveforms on an oscilloscope.

## Teaching Tips

1. Read through the activity before beginning.
2. Reproduce activity sheets for each student, or lab group, before the activity.
3. Organize all equipment and supplies before the activity.

## Instructional Strategy

- Explain alternating and direct current flow.
- Explain and demonstrate the conversion of chemical energy to electrical energy by the chemical action of a cell or battery.
- Explain and demonstrate the construction and operation of a center-tapped, step-down transformer.
- Explain and demonstrate the operation and testing function of an oscilloscope.

## Equipment/Supplies

1. 1.5-volt "D" cell
2. 6-volt lantern battery
3. 120-volt input/12.6-volt output center-tapped, step-down transformer with AC line cord
4. B&K Precision 1405 single-trace oscilloscope (or comparable) with test leads

## Evaluation Key

1. Instructor evaluation of student's ability to follow the procedures of the activity sheet.
2. Instructor evaluation of student's ability to obtain desired information from the oscilloscope.
3. Instructor evaluation of student's ability to follow safety guidelines established for test equipment and voltage sources.

# AC-DC WAVEFORM/OSCILLOSCOPE FAMILIARIZATION

*Experiment with AC and DC power sources and the oscilloscope.*

## Objectives

- To operate the oscilloscope to given standards with measuring direct and alternating current waveform characteristics
- To identify direct current waveform characteristics on the oscilloscope
- To identify alternating current waveform characteristics on the oscilloscope
- To identify the difference between direct and alternating current flow

## Vocabulary/Concepts Reinforced

- Direct current
- Alternating current
- Oscilloscope
- Cathode-ray tube
- Cell
- Battery
- Center-tapped, step-down transformer

## Equipment/Supplies

- 1.5-volt "D" cell
- 6-volt lantern battery
- 120-volt input/12.6-volt output center-tapped, step-down transformer with AC line cord
- B&K Precision 1405 single-trace oscilloscope (or comparable) with test leads

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## Introduction

The oscilloscope is a very important testing instrument for electronic circuits. The oscilloscope is an especially useful tool for testing electronic communication circuits. The oscilloscope converts voltage values to visual waveforms on a cathode-ray tube (CRT). The CRT of an oscilloscope is very similar to the picture tube of a black-and-white television set. The waveform produced by the electron beam of the CRT is controlled by the amount of voltage produced by the signal being tested and the speed and direction of the electron movement of the signal. Figure 1 shows the location and function of the controls on the front panel of the B&K Precision 1405 oscilloscope.

The movement of electrons in a circuit is called current flow. Current flow in a circuit is classified into the two major categories—direct current and alternating current. A direct current power source produces a movement of electrons in one direction. The curent flow travels from the negative terminal to the positive terminal of the power source. Chemical cells and batteries are the most common direct current power source. Cells convert chemical energy to electrical energy. Batteries consist of two, or more, cells connected together in a single case to increase voltage output.

The two main components of a cell are the electrodes, and the electrolyte is the chemical solution that interacts with the electrodes to produce electrical energy. The electrolyte of a cell may be in a liquid or paste form. A cell with a liquid electrolyte is called a wet cell. A cell with a paste electrolyte is called a dry cell.

Cells and batteries are also classified by their ability to be recharged. A cell that cannot be recharged is called a primary cell. A cell that can be recharged is called a secondary cell.

The 1.5-volt "D" cell and the 6-volt lantern battery used in this activity are examples of carbon-zinc cells. Carbon-zinc cells are one of the oldest and most widely used primary dry cells. The electrolyte of a carbon-zinc cell is a paste of ammonium chloride and zinc chloride dissolved in water. The negative electrode is a zinc can, and the positive electrode is a mixture of manganese dioxide and powdered carbon. The maximum voltage of a common carbon-zinc cell is approximately 1.5 volts.

Electric energy is commonly supplied in the form of alternating current. An alternating current power source produces a movement of electrons that changes direction at a periodic rate. The waveform produced by alternating current flow is called a sine wave.

A *transformer* is a device that raises or lowers alternating current voltage. A transformer operates on the principle of mutual inductance. Mutual inductance occurs when an expanding and collapsing magnetic field produced by an alternating current flow through one coil induces an alternating current voltage in a second coil.

A typical transformer consists of two insulated coils, or windings, and a core material. The coil of a transformer attached to the power source of a circuit is called the primary winding. The coil of a transformer attached to the load of a circuit is called the secondary winding. When alternating current produces an expanding and collapsing magnetic field around the primary winding, alternating current is induced in the secondary winding. The primary and secodary coils of a transformer are wound around a core material. The core material of most transformers is made up of laminated iron strips.

The two most common types of transformers are step-up and step-down transformers. A *step-up* tranformer raises output, or secondary, voltage and lowers output current. In a step-up transformer, there are more secondary windings wound around the core than primary windings. It is the increased number of secondary windings in a step-up transformer that produces an increase in output voltage and a decrease in output current. A *step-down* tranformer lowers output voltage and raises output current. In a step-down transformer, there are less secondary windings wound around the core than primary windings. It is the decreased number of secondary windings in a step-down transformer that produces a decrease in the output voltage and the increase in the output current.

A center-tapped, step-down transformer will be used in this activity. In the center-tapped transformer, the secondary winding is divided into two windings with a common connection. A center-tapped transformer provides two voltages with reference to a common center tap. The center-tapped, step-down transformer in this activity will produce an output voltage of approximately 12.6 volts across the two outer terminals and approximately 6.3 volts across the center tap and either of the outer terminals.

In this activity the oscilloscope will be used to identify direct current flow produced by a 1.5-volt "D" cell and a 6-volt lantern battery. The direct current waveform will be compared with the alternating current waveform produced by the secondary terminals of the center-tapped, step-down transformer.

**Procedure**

1. Plug in the oscilloscope line cord to an AC outlet, and position it so that you can easily reach the controls and view the CRT.
2. Connect the black test probe to the grounding terminal of the oscilloscope.
3. Connect the red test probe to the VERT INPUT terminal of the oscilloscope.
4. Set the SWEEP RANGE controls of the oscilloscope to the 10-100 setting.
5. Set the V ATT control of the oscilloscope to the 1/100 setting.
6. Turn on the oscilloscope.
7. Locate the 6-volt lantern battery and 1.5-volt "D" cell.
8. Connect the black probe of the oscilloscope to the negative terminal of the 6-volt lantern battery.
9. Connect the red probe of the oscilloscope to the positive terminal of the 6-volt latern battery.
10. Record the effect on the line of the CRT of the oscilloscope.
11. Adjust the V GAIN control of the oscilloscope until the waveform is four squares above the centerline on the screen of the CRT.
12. Reverse the oscilloscope probe connections on the 6-volt lantern battery terminals.
13. Record the effect on the line of the CRT of the oscilloscope. Explain the reason for your results.

14. Disconnect the oscilloscope probes from the terminals of the 6-volt lantern battery.
15. Connect the red probe of the oscilloscope to the positive terminal of the 1.5-volt "D" cell.
16. Connect the black probe of the oscilloscope to the negative terminal of the 1.5-volt "D" cell.
17. Compare the effect on the line of the CRT produced by the 1.5-volt "D" cell with the effect on the line of the CRT produced by the 6-volt lantern battery. Explain the reason for your results.

18. Reverse the oscilloscope probe connections on the 1.5-volt "D" cell terminals.
19. Record the effect on the line of the CRT of the oscilloscope. Expain the reason for your results.

20. Disconnect the oscilloscope probes from the terminals of the 1.5-volt "D" cell.
21. Locate the center-tapped, step-down transformer.
22. Plug in the line cord of the center-tapped to an AC outlet.
23. Connect the black probe of the oscilloscope to the center terminal of the center-tapped, step-down transformer.
24. Connect the red probe of the oscilloscope to one of the outer terminals of the center-tapped, step-down transformer.
25. Adjust the SWEEP VARI control to produce approximately two sine waves on the screen of the CRT.
26. Position the waveform in the center of the oscilloscope screen.

27. Adjust the V GAIN control of the oscilloscope until the positive peak of the waveform is two squares above the centerline, and the negative peak of the waveform is two squares below the centerline of the CRT screen.
28. Draw the waveform.

29. With the black probe connected to the center terminal of the transformer, disconnect the red probe from the outer terminal of the transformer and connect it to the other outer terminal.
30. What effect does this have on the waveform? Explain the reason for your results.

31. With the red probe connected to the outer terminal of the transformer, disconnect the black probe from the center terminal and connect it to the other outer terminal.
32. What effect does this have on the waveform? Explain the reason for your results.

33. How many squares are there from the centerline of the CRT screen to each peak?
34. Reverse the connection of the two oscilloscope probes.
35. What effect does this have on the waveform? Explain the reason for your results.

36. Adjust the V GAIN control until the positive peak is three squares above the centerline and the negative peak is three squares below the centerline of the CRT screen.
37. Set the SWEEP RANGE control of the oscilloscope to the 100-1K setting.
38. How does this affect the waveform? Explain the reason for your results.

39. Return the SWEEP RANGE control of the oscilloscope to the 10-100 setting.
40. Set the V ATT control of the oscilloscope to the 1/10 setting.
41. How does this affect the waveform? Explain the reason for your results.

42. Disconnect the oscilloscope probes from the terminals of the transformer.
43. Turn off the oscilloscope.
44. Unplug the line cords of the transformer and the oscilloscope from the AC outlet.
45. Disconnect the probes from the oscilloscope.

*Questions*

1. Why does direct current produce the effect on the screen of the CRT of the oscilloscope observed in this activity?

2. Why does alternating current produce the effect on the screen of the CRT of the oscilloscope observed in this activity?

### Evaluation

Evaluation is based on your ability to use the oscilloscope to observe direct and alternating current flow following the procedure steps of the activity.

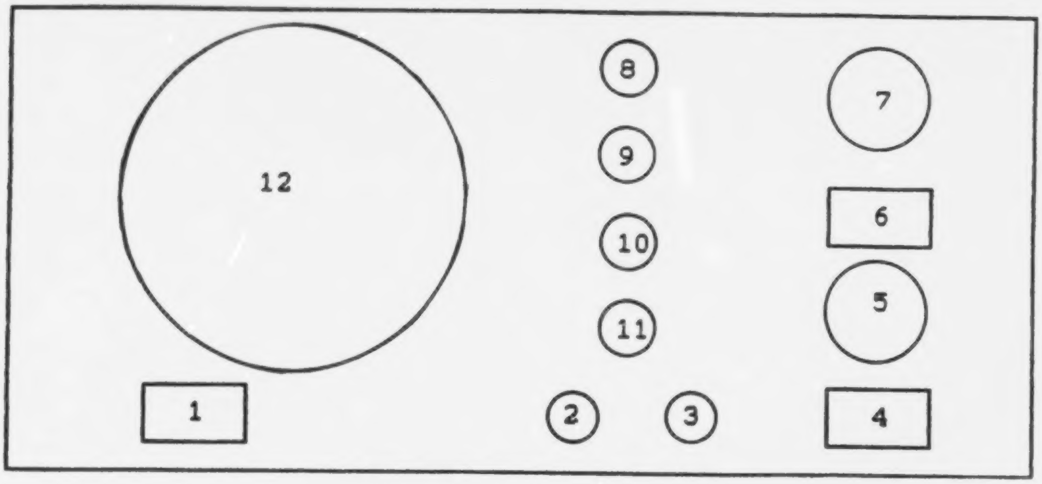

**Figure 1. Oscilloscope Controls**

1. POWER—on/off power control for the oscilloscope

2. ⏚ (ground)—grounding terminal

3. VERT INPUT (vertical input)—input terminal for the vertical signal

4. DC/AC—setting for the signal source current type being tested

5. V ATT (vertical attenuator)—controls the height of the waveform that appears on the CRT produced by the voltage level of the signal being measured

| **Signal Voltage** | **V ATT setting** |
|---|---|
| 0.8 V p-p (0.3 V rms or less)— | 1 |
| 0.2 to 8 V p-p (0.07 to 3 V rms)— | 1/10 |
| above 2 V p-p (0.7 V rms)— | 1/100 |

6. SYNC-INT/EXT—internal synchronization locks in the waveform image frequency to stop it from moving across the CRT

7. SWEEP RANGE—controls the width of the waveform that appears on the CRT produced by the frequency of the signal being measured

8. SWEEP VARI—fine tuning control for the SWEEP RANGE control

9. ◁ ▷ POSITION—moves the waveform to the left or right of the CRT

10. △ ▽ POSITION—moves the waveform up or down on the CRT

11. V GAIN (vertical gain)—fine tuning control for the V ATT control

12. CRT (cathode-ray tube)—display screen of the oscilloscope

ELECTRICITY/ELECTRONICS SYSTEMS
INSTRUCTOR'S RESOURCE SHEET 32
(1 DAY)

# OHM'S LAW

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**Essential Elements:** Common: 6A, B; 8C; 9A, B
Specific: 1, 2, 3, 9
**TAAS Objectives:** Mathematics: C 1, 2, 4; O 3, 4
Language Arts: RC 4, 5; WC 1

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## Activity Summary

This activity is designed to give students the opportunity to calculate the voltage, current, and resistance values of simple series circuits using the equations of Ohm's law. Students will also be given the opportunity to measure the voltage, current, and resistance values of simple series circuits using the voltmeter, milliammeter, and ohmmeter functions of a multimeter. This activity will also enable the student to understand the use of metric prefixes in electrical calculations and measurements.

## Teaching Tips

1. Read through the activity before beginning.
2. Reproduce activity sheets for each student, or lab group, before the activity.
3. Organize all equipment and supplies before the activity.

## Instructional Strategy

- Explain and demonstrate the electrical properties of voltage, current, and resistance.
- Explain and demonstrate the use of metric prefixes to abbreviate values of voltage, current, and resistance.
- Explain and demonstrate the use of cells and batteries as power supplies for circuits.
- Explain and demonstrate the construction and operation of an incandescent lamp.
- Explain and demonstrate the construction and use of a carbon composition resistor.
- Explain and demonstrate the construction and use of a single pole switch.
- Explain and demonstrate the use of symbols for electrical components and the use of schematic diagrams to represent electrical circuits.
- Explain and demonstrate the construction of a simple series circuit on a proto-board.
- Explain and demonstrate the use of the voltmeter function of a multimeter.
- Explain and demonstrate the use of the milliammeter function of a multimeter.
- Explain and demonstrate the use of the ohmmeter function of a multimeter.

## Equipment/Supplies

1. 6-volt lantern batteries with various levels of voltage output
2. Proto-board with connecting wires
3. No. 47 incandescent lamp (or comparable) with holder
4. Single-pole slide switch
5. 1/2-watt carbon composition resistors of various resistance values
6. Analog, or digital, multimeter with test probes
7. Calculator

### Evaluation Key

1. Instructor evaluation of student's ability to calculate voltage, current, and resistance values of a circuit using Ohm's law equations.
2. Instructor evaluation of student's ability to interpret schematic diagrams and to construct a simple series circuit.
3. Instructor evaluation of student's ability to interpret Resistor Color Code information on each resistor.
4. Instructor evaluation of student's ability to measure voltage values with the voltmeter function of a multimeter.
5. Instructor evaluation of student's ability to measure current values with the milliammeter function of a multimeter.
6. Instructor evaluation of student's ability to measure the resistance value of each resistor using the ohmmeter function of a multimeter.
7. Instructor evaluation of student's ability to follow safety guidelines established for test equipment and circuit evaluation.
8. Instructor evaluation of student's ability to follow the procedures of the activity sheet.

# OHM'S LAW

*Experiment with Ohm's law calculations and electrical properties measurements.*

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## Objectives

- To construct a circuit following a schematic diagram
- To identify voltage, current, and resistance characteristics of a circuit
- To calculate unknown electrical properties using the equations of Ohm's law
- To measure the value of electrical properties of a circuit using the different functions of a multimeter

## Vocabulary/Concepts Reinforced

- Voltage
- Volt
- Current
- Ampere
- Milliampere
- Resistance
- Ohm
- Kilohm
- Resistor
- Resistor Color Code
- Incandescent lamp
- Ohm's law
- Multimeter
- Voltmeter
- Milliammeter
- Ohmmeter

## Equipment/Supplies

- 6-volt lantern batteries with various levels of voltage output
- Proto-board with connecting wires
- No. 47 incandescent lamp (or comparable) with holder
- Single-pole slide switch
- 1/2-watt carbon composition resistors of various resistance values
- Analog, or digital, multimeter with test probes
- Calculator

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## Introduction

The investigation of the relationship between voltage, current, and resistance in a circuit is fundamental to all electrical and electronic circuits. Voltage is the electrical force, or pressure, applied to a circuit. The unit of measurement for voltage is the volt. Current is the movement, or flow, of electrons in a circuit. Resistance is the opposition to the flow of current in a circuit. The unit used to measure resistance is the ohm.

In most electronic circuits, the current level is very low. To abbreviate the decimal number values for current, the metric prefixes *milli* and *micro* are used. The metric prefix milli represents 0.001. Many current flow values are measured in milliamperes. One milliampere of current flow is equal to 0.001 ampere. The metric prefix micro represents 0.000001. Very small amounts of current flow are measured in microamperes. One microampere of current flow is equal to 0.000001 ampere.

The resistance value of many circuits is quite large. To abbreviate the large number values for resistance, the metric prefixes *kilo* and *Mega* are used. The metric prefix kilo represents 1,000. Many resistance values are measured in kilohms. One kilohm of resistance is equal to 1,000 ohms. The metric prefix Mega represents 1,000,000. Very large amounts of resistance are measured in megohms. One megohm of resistance is equal to 1,000,000 ohms.

Metric prefixes are widely used to abbreviate very small or very large number values for electrical property units. The metric prefix units cannot be used in an equation. When using numbers in calculations, such as the Ohm's law equations, base units of volts, amperes, and ohms must be used.

In 1827, Georg Simon Ohm established a definite relationship between voltage, current, and resistance in a circuit, which is known as Ohm's law. Ohm's law can be stated, or written, as a mathematical equation. When Ohm's law is written as a mathematical equation, the following letters are used to represent voltage, current, and resistance:

E or V = voltage
I = current
R = resistance

According to Ohm's law, the voltage required to force a given amount of current through a circuit is equal to the product of the current and the resistance in the circuit. This statement is written as the following mathematical equation.

$$E = I \cdot R$$

Ohm's law also states that the amount of current in a circuit is equal to the voltage applied to the circuit divided by the resistance of the circuit. This statement is written as the following mathematical equation.

$$I = \frac{E}{R}$$

Finally, Ohm's law states that the resistance in a circuit is equal to the voltage applied to the circuit divided by the amount of current in the circuit. This statement is written as the following mathematical equation.

$$R = \frac{E}{I}$$

These three equations can be used to calculate an unknown value of voltage, current, or resistance in any circuit. There are other generalizations that can be made from the three Ohm's law equations. One generalization is that current flow in a circuit is directly proportional to the voltage applied to the circuit. When the voltage applied to a circuit increases and the resistance in the circuit remains constant, current will increase in the circuit. When the voltage applied to a circuit decreases and the resistance in the circuit remains constant, current will decrease in the circuit.

Another generalization that can be made is that current flow in a circuit is inversely proportional to the resistance of the circuit. When the resistance of a circuit increases and the applied voltage remains constant, current will decrease in the circuit.

This activity will demonstrate the relationship between voltage, current, and resistance in simple circuits. Knowledge of electrical component identification, schematic diagram interpretation, circuit construction, and multimeter operation is also essential in this activity.

## Procedure

1. Locate a 6-volt lantern battery, proto-board, connecting wire, single-pole switch, lamp and socket, and multimeter with test probes.
2. Construct the circuit drawn in Figure 1. The circuit switch should be in the "off" position.
3. Place the red test probe into the positive terminal of the multimeter.
4. Place the black test probe into the negative terminal of the multimeter.
5. Set the multimeter to the proper voltmeter range to measure the voltage produced by the lantern battery.
6. Measure and record the voltage produced by the lantern battery by connecting the probes of the multimeter to **Test Points A** and **B** on the circuit. (Observe polarity.)

$V_1$ = __________volts

7. Set the multimeter to the highest milliammeter range to measure the current flow through the circuit.
8. Disconnect the wire at **Test Points B** and **C**, and place the probes of the multimeter in the circuit at **Test Points B** and **C**. (Observe polarity.)
9. Turn the circuit switch to the "on" position. The filament of the lamp should begin to glow.
10. Lower the milliammeter range of the multimeter until an accurate current reading can be made. Record the value of current flow in the circuit.

I = __________ milliamperes
I = __________ amperes

11. Turn the circuit switch to the "off" position, and replace the wire at **Test Points B** and C.
12. Calculate the resistance value produced by the lamp in the circuit, using the voltage value measured in **Step 6** and the current value measured in **Step 10**.

$$R_{lamp_1} = \frac{E}{I}$$

$R_{lamp_1}$ =______________ohms
$R_{lamp_1}$ =______________kilohms

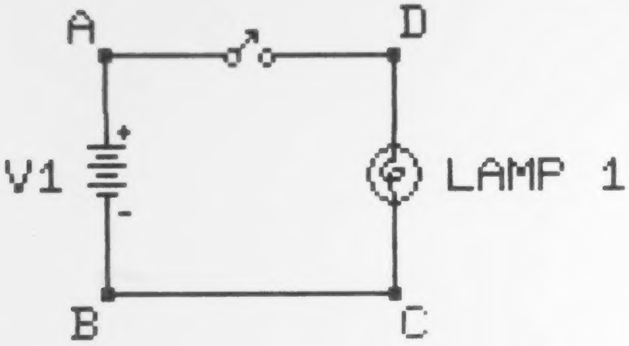
A
D
V1
+
-
LAMP 1
B
C

Figure 1

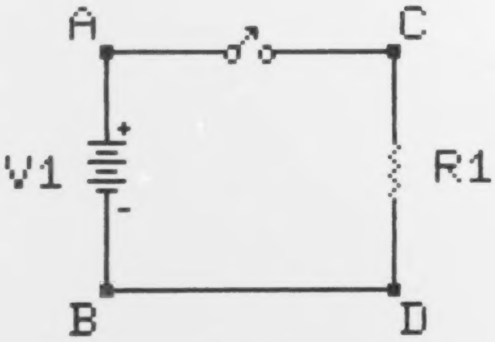

Figure 2

13. Remove the lamp from the circuit, and replace it with a 1/2-watt carbon composition resistor to produce the circuit shown in Figure 2.
14. Using the Resistor Color Code, calculate the resistance value of $R_1$.

$R_1$ =________________ohms

$R_1$ =________________kilohms

15. Set the multimeter to the proper ohmmeter range to measure the resistance produced by $R_1$.
16. Measure and record the resistance produced by $R_1$ by connecting the probes of the multimeter to **Test Points C and D** on the circuit.

$R_1$ =________________kilohms

$R_1$ =________________ohms

17. Calculate the current flow in the circuit, using the voltage value measured in **Step 6** and the resistance value measured in **Step 16.**

$$I = \frac{E}{R}$$

I =___________ amperes

I =___________ milliamperes

18. Set the multimeter to the proper milliammeter range to measure the current flow through the circuit.

19. Disconnect the wire at **Test Points B** and **D**, and place the probes of the multimeter in the circuit at **Test Points B** and **D**. (Observe polarity.)

20. Turn the circuit switch to the "on" position. Record the value of current flow in the circuit.

I =___________ milliamperes

I =___________ amperes

21. Turn the circuit switch to the "off" position, and reconnect the wire at **Test Points B** and **D**.

22. How does the calculated value of current flow in the circuit compare with the measured value of current flow in the circuit?

23. Disconnect the resistor from the circuit, and replace it with a resistor of another value.

24. Using the Resistor Color Code, calculate the resistance value of $R_1$.

$R_1$ =________________ohms

$R_1$ =________________kilohms

25. Set the multimeter to the proper ohmmeter range to measure the resistance produced by $R_1$.

26. Measure and record the resistance produced by $R_1$ by connecting the probes of the multimeter to **Test Points C** and **D** on the circuit.

$R_1$ =________________kilohms

$R_1$ =________________ohms

27. Calculate the current flow in the circuit, using the voltage value measured in **Step 6** and the resistance value measured in **Step 26**.

$$I = \frac{E}{R}$$

I =__________ amperes

I =__________ milliamperes

28. Set the multimeter to the proper milliammeter range to measure the current flow through the circuit.

29. Disconnect the wire at **Test Points B** and **D** and place the probes of the multimeter in the circuit at **Test Points B** and **D**. (Observe polarity.)

30. Turn the circuit switch to the "on" position. Record the value of current flow in the circuit.

I =__________ milliamperes

I =__________ amperes

31. Turn the circuit switch to the "off" position, and reconnect the wire at **Test Points B** and **D**.

32. How does the current flow measurement in **Step 20** compare with the current flow measurement in **Step 30**?

33. What is the reason for the difference in the two current readings?

34. Replace the lantern battery in the circuit with another lantern battery.

35. Set the multimeter to the highest milliammeter range to measure the current flow through the circuit.

36. Disconnect the wire at **Test Points B** and **D**. (Observe polarity.)

37. Turn the circuit switch to the "on" position. Lower the range of the milliammeter to obtain the most accurate reading, and record the value of current flow in the circuit.

I =__________ milliamperes

I =__________ amperes

38. Turn the circuit switch to the "off" position, and reconnect the wire at **Test Points B** and **D**.

39. Calculate the value of voltage produced by the lantern battery, using the resistance value measured in **Step 26** and the current value measured in **Step 37**.

    $E = I \cdot R$
    $E =$ _______________ volts

40. Set the multimeter to the proper voltmeter range to measure the voltage produced by the lantern battery.
41. Measure and record the voltage produced by the lantern battery by connecting the probes of the multimeter to **Test Points A** and **B** on the circuit.
42. How does the calculated value of the voltage produced by the lantern battery compare with the measured value of the voltage produced by the lantern battery?

43. Is there any difference between the current value measured in **Step 30** and the current value measured in **Step 37**? Why could there be a difference in the two current values?

44. Disconnect the components from the proto-board.
45. Turn off the multimeter, and disconnect the probes from the multimeter.

## Evaluation

Evaluation is based on your ability to calculate electrical properties using Ohm's law equations. You will also be evaluated on your ability to safely construct and test simple series circuits.

# SERIES RESISTIVE CIRCUITS

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| | |
|---|---|
| **Essential Elements:** | Common: 6A, 6B, 8C, 9A, 9B<br>Specific: 1, 2, 3, 9 |
| **TAAS Objectives:** | Mathematics: C 1, 2, 4; O 1-4<br>Language Arts: RC 4, 5; WC 1 |

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## Activity Summary

This activity is designed to provide students with the opportunity to calculate the voltage, current, and resistance values of simple series circuits. Students will also be given the opportunity to measure the voltage, current, and resistance values of simple series circuits using the voltmeter, milliammeter, and ohmmeter functions of a multimeter. This activity will also enable the student to understand the use of metric prefixes in electrical calculations and measurements.

## Teaching Tips

1. Read through the activity before beginning.
2. Reproduce activity sheets for each student, or lab group, before the activity.
3. Organize all equipment and supplies before the activity.

## Instructional Strategy

- Explain and demonstrate the relationship between the electrical properties of voltage, current, and resistance in a series circuit.
- Explain and demonstrate the use of metric prefixes to abbreviate values of voltage, current, and resistance.
- Explain and demonstrate the use of symbols for electrical components and the use of schematic diagrams to represent electrical circuits.
- Explain and demonstrate the construction of simple series circuits on a proto-board.
- Explain and demonstrate the use of the voltmeter function of a multimeter.
- Explain and demonstrate the use of the milliammeter function of a multimeter.
- Explain and demonstrate the use of the ohmmeter function of a multimeter.

## Equipment/Supplies

1. 1.5-volt "D" cells
2. Two "D" cell holder
3. 6-volt lantern battery
4. Proto-board with connecting wires
5. Single-pole slide switch
6. 1/2-watt carbon composition resistors of various resistance values
7. Analog, or digital, multimeter with test probes
8. Calculator

## Evaluation Key

1. Instructor evaluation of student's ability to calculate voltage, current, and resistance values of a series circuit.
2. Instructor evaluation of student's ability to interpret schematic diagrams for series circuits.
3. Instructor evaluation of student's ability to construct a simple series circuit.

4. Instructor evaluation of student's ability to interpret Resistor Color Code information on each resistor.
5. Instructor evaluation of student's ability to measure voltage values with the voltmeter function of a multimeter.
6. Instructor evaluation of student's ability to measure current values with the milliammeter function of a multimeter.
7. Instructor evaluation of student's ability to measure the resistance value of each resistor using the ohmmeter function of a multimeter.
8. Instructor evaluation of student's ability to follow safety guidelines established for test equipment and circuit evaluation.
9. Instructor evaluation of student's ability to follow the procedures of the activity sheet.

# SERIES RESISTIVE CIRCUITS

*Experiment with series circuit calculations, construction, and testing.*

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## Objectives

- To construct series circuits following a schematic diagram
- To identify voltage, current, and resistance characteristics of a series circuit
- To calculate unknown electrical properties for a series circuit
- To measure the value of electrical properties of a series circuit using the different functions of a multimeter

## Vocabulary/Concepts Reinforced

- Series circuit
- Voltage
- Voltage drop
- Current
- Resistance
- Multimeter
- Voltmeter
- Milliammeter
- Ohmmeter

## Equipment/Supplies

- 1.5-volt "D" cells
- Two "D" cell holder
- 6-volt lantern battery
- Proto-board with connecting wires
- Single-pole slide switch
- 1/2-watt carbon composition resistors of various resistance values
- Analog, or digital, multimeter with test probes
- Calculator

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## Introduction

A series circuit provides only one path for current flow. When the circuit switch is closed, the voltage, or electrical force, produced by the power source forces electrons to flow through the switch, through the conductors, through the load, and back to the power source. In a direct current series circuit, the electrons flow from the negative terminal of the power source, through the circuit, to the positive terminal of the power source.

Since there is only one path for current flow in a series circuit, breaking the current path at any point will cause current flow to cease in the entire circuit. The single path for current flow in a series circuit also provides only one value for current flow through the entire circuit. This means that there are as many electrons flowing from any point of a series as there are flowing to that point. The value of current flow in a series circuit remains constant throughout the circuit.

When resistive components are connected in series, the current in the circuit must overcome the resistance of each resistive component. The total resistance in a series circuit is equal to the sum of the resistance values of all the resistive components in a series circuit. This statement can be expressed mathematically by the following equation.

$$R_T = R_1 = R_2 = R_3 ... + R_{(n)}$$

$R_T$ = total resistance

$R_1, R_2, R_3 ... R_{(n)}$ = any number of resistors in the circuit

Voltage in a series circuit must be distributed among the resistive components in direct proportion to their resistance in order to maintain a constant current flow through the circuit. The voltage required to force electrons through any resistor is called a *voltage drop*. The sum of the voltage drops in any series circuit is equal to the total applied voltage. This statement can be expressed mathematically by the following equation.

$$E_T = E_{R_1} + E_{R_2} + E_{R_3} ... + E_{R_{(n)}}$$

$E_T$ = total voltage

$E_{R_1}, E_{R_2}, E_{R_3} ... E_{R_{(n)}}$ = voltage drop across each resistor

Direct current power sources, such as cells and batteries, are often connected in series. Connecting cells, or batteries, in series increases the total voltage applied to the circuit. To increase total voltage in series, cells are arranged so that the positive terminal of one cell is connected to the negative terminal of the next cell. This statement can be expressed mathematically by the following equation.

$$E_T = E_1 = E_2 = E_3 ... + E_{(n)}$$

$E_T$ = total voltage

$E_1, E_2, E_3 ... E_{(n)}$ = voltage sources in the circuit

In the series circuits for this activity, the current level will be very low. To abbreviate the decimal number values for current, the metric prefixes *milli* and *micro* are used. The metric prefix milli represents 0.001. Many current flow values are measured in milliamperes. One milliampere of current flow is equal to 0.001 ampere. The metric prefix micro represents 0.000001. Very small amounts of current flow are measured in microamperes. One microampere of current flow is equal to 0.000001 ampere.

The resistance value of the resistors for this activity may be quite large. To abbreviate the large number values for resistance, the metric prefixes *kilo* and *Mega* are used. The metric prefix kilo represents 1,000. Many resistance values are measured in kilohms. One kilohm of resistance is equal to 1,000 ohms. The metric prefix Mega represents 1,000,000. Very large amounts of resistance are measured in megohms. One megohm of resistance is equal to 1,000,000 ohms.

Metric prefixes are widely used to abbreviate very small or very large number values for electrical property units. The metric prefix units cannot be used in an equation. When using numbers in calculations, the base units of volts, amperes, and ohms must be used.

The Ohm's law equations for calculating current and voltage must be used in this activity. The following abbreviations are used in Ohm's law equations.

E or V = voltage
I = current
R = resistance

The Ohm's law equation for voltage indicates that the voltage applied to a circuit is equal to the product of the circuit current and the circuit resistance.

$$E = I \cdot R$$

The Ohm's law equation for current indicates that the amount of current in a circuit is equal to the voltage applied to the circuit divided by the resistance of the circuit.

$$I = \frac{E}{R}$$

This activity will demonstrate the construction of series circuits from a schematic diagram. Cells and batteries will be used as the power source for the series circuits in the activity, and carbon composition resistors are used as the loads in the circuit. The multimeter will be used to test voltage, current, and resistance values of the circuits.

**Procedure**

1. Locate two 1.5-volt "D" cells, two "D" cell holder, proto-board, connecting wire, single-pole switch, 1/2-watt carbon composition resistor, and multimeter with test probes.
2. Place the red test probe into the positive terminal of the multimeter.
3. Place the black test probe into the negative terminal of the multimeter.
4. Set the multimeter to the proper voltmeter range, and measure the voltage produced by each "D" cell.

cell 1 = __________volts
cell 2 = __________volts

5. Insert the two "D" cells into the holder.
6. Calculate the total voltage produced by the two cells when they are connected in series in the holder.

$V_T = V_1 + V_2$
$V_T$ =____________volts

7. Set the multimeter to the proper voltmeter range, and measure the total voltage produced by the two "D" cells.

$V_T$ =____________volts

8. How does the measured value of total voltage compare to the calculated value of total voltage?

9. Construct the circuit drawn in Figure 1. The circuit switch should be in the "off" position.
10. Using the Resistor Color Code, calculate the resistance value of $R_1$.

$R_1$ =____________ohms
$R_1$ =____________kilohms

11. Set the multimeter to the proper ohmmeter range to measure the resistance produced by $R_1$.
12. Measure and record the resistance produced by $R_1$ by connecting the probes of the multimeter to **Test Points D** and **E** on the circuit.

$R_1$ =____________kilohms
$R_1$ =____________ohms

13. Set the multimeter to the proper voltmeter range to measure the voltage drop across $R_1$.
14. Turn the circuit switch to the "on" position.
15. Measure the voltage drop across $R_1$ at **Test Points D** and **E**.

$V_{R_1}$ =______________volts

16. How does the voltage drop across $R_1$ compare with the total voltage?

17. Turn the circuit switch to the "off" position.
18. Calculate the current flow in the circuit, using the voltage value measured in **Step 7** and the resistance value measured in **Step 12**.

$$I_T = \frac{E_T}{R_T}$$

$I_T$ = _______________amperes
$I_T$ = _______________milliamperes

19. Set the multimeter to the proper milliammeter range to measure the current flow through the circuit.
20. Disconnect the wire at **Test Points C** and **D**, and place the probes of the multimeter in the circuit at **Test Points C** and **D**. (Observe polarity.)
21. Turn the circuit switch to the "on" position. Record the value of current flow in the circuit.

$I_T$ = _______________milliamperes
$I_T$ = _______________amperes

22. Turn the circuit switch to the "off" position, and reconnect the wire at **Test Points C** and **D**.
23. How does the calculated value of current flow in the circuit compare with the measured value of current flow in the circuit?

24. Disconnect the circuit.
25. Locate the 6-volt lantern battery and two resistors of different resistance values.
26. Construct the series circuit drawn in Figure 2. The circuit switch should be in the "off" position.
27. Set the multimeter to the proper voltmeter range to measure the voltage produced by the lantern battery.
28. Measure and record the voltage produced by the lantern battery by connecting the probes of the multimeter to **Test Points A** and **B** on the circuit. (Observe polarity.)

$V_1$= _______________volts

29. Calculate the resistance value of each resistor using the Resistor Color Code.

$R_1$ =_______________ohms
$R_1$ =_______________kilohms
$R_2$ =_______________ohms
$R_2$ =_______________kilohms

30. Set the multimeter to the proper ohmmeter range, and measure the resistance produced by $R_1$ at **Test Points D** and **E**.

$R_1$ =_______________ohms
$R_1$ =_______________kilohms

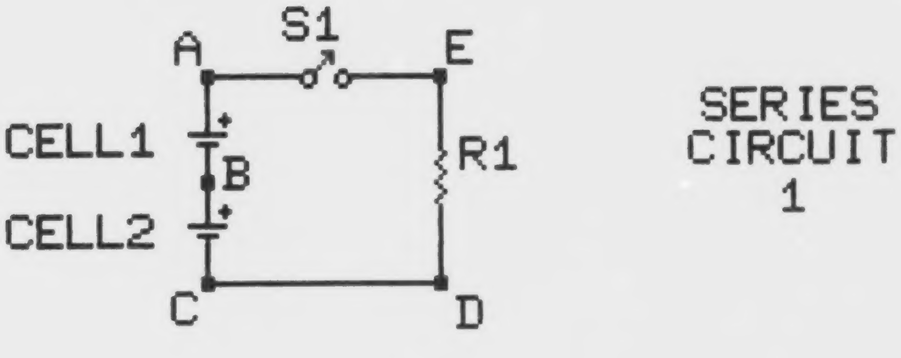
S1
A
E
CELL1
B
CELL2
R1
C
D
SERIES
CIRCUIT
1

Figure 1

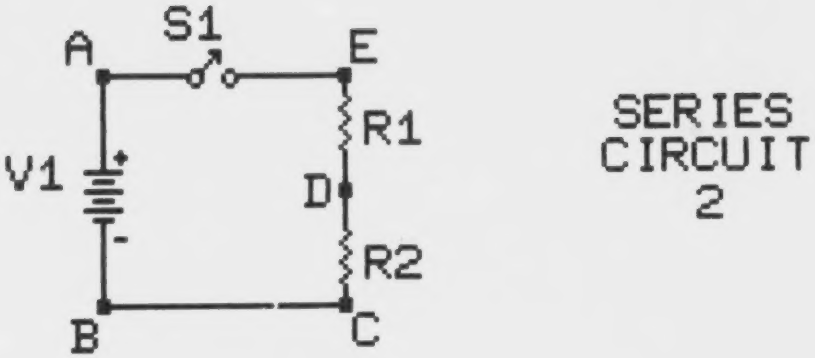
S1
A
E
R1
V1
D
R2
B
C
SERIES
CIRCUIT
2

Figure 2

31. Set the multimeter to the proper ohmmeter range, and measure the resistance produced by $R_2$ at **Test Points C** and **D.**

$R_2$ = ________________ohms

$R_2$ = ________________kilohms

32. Calculate the total resistance of the circuit using the measured values of each resistor.

$R_T = R_1 + R_2$

$R_T$ = ________________ohms

$R_T$ = ________________kilohms

33. Set the multimeter to the proper ohmmeter range, and measure the total resistance at **Test Points C** and **E.**

$R_T$ = ________________ohms

$R_T$ = ________________kilohms

34. How does the measured value of total resistance compare with the calculated value of total resistance?

35. Calculate the current value for the circuit using Ohm's law.

$$I = \frac{E_T}{R_T}$$

$I_T$ = ________________amperes

$I_T$ = ________________milliamperes

36. Disconnect the wire at **Test Points B** and **C**, and place the probes of the multimeter in the circuit at **Test Points B** and **C**. (Observe polarity.)
37. Turn the circuit switch to the "on" position. Record the value of current flow in the circuit.

$I_T$ = ________________amperes

$I_T$ = ________________milliamperes

38. Turn the circuit switch to the "off" position, and reconnect the wire at **Test Points B** and **D.**

39. How does the calculated value of current flow in the circuit compare with the measured value of current flow in the circuit?

40. Calculate the voltage drop across $R_1$, using the resistance value for $R_1$ measured in **Step 37**.

$$V_{R_1} = I_T \cdot R_1$$

$V_{R_1}$ = ____________volts

41. Calculate the voltage drop across $R_2$, using the resistance value for $R_2$ measured in **Step 31** and the current value measured in **Step 37**.

$$V_{R_2} = I_T \cdot R_2$$

$V_{R_2}$ = ____________volts

42. Calculate the total voltage drop in the circuit, using the calculated voltage drop values across $R_1$ and $R_2$ found in **Steps 40** and **41**.

$$V_T = V_{R_1} + V_{R_2}$$

$V_T$ =____________volts

43. Set the multimeter to the proper voltmeter range to measure the voltage drop across **$R_1$**.
44. Turn the circuit switch to the "on" position.
45. Measure and record the voltage drop across $R_1$ by placing the probes of the multimeter at **Test Points D** and **E**. (Observe polarity.)

$V_{R_1}$ = ____________volts

46. How does the measured voltage drop across $R_1$ compare with the calculated voltage drop across $R_1$?

47. Set the multimeter to the proper voltmeter range to measure the voltage drop across **$R_2$**.
48. Measure and record the voltage drop across $R_2$ by placing the probes of the multimeter at **Test Points D** and **E**. (Observe polarity.)

$V_{R_2}$ =____________volts

49. How does the measured voltage drop across $R_2$ compare with the calculated voltage drop across $R_2$?

50. Calculate the total voltage drop in the circuit using the measured voltage drop values across $R_1$ and $R_2$ found in **Steps 45** and **48**.

$$V_T = V_{R_1} + V_{R_2}$$

$V_T$ =____________volts

51. Set the multimeter to the proper voltmeter range to measure the total voltage drop in the circuit.

52. Measure and record the total voltage drop across the circuit by placing the probes of the multimeter at **Test Points C** and **E**. (Observe polarity.)

$V_T$ =____________volts

53. How does the measured value of total voltage drop compare with the total voltage drop values calculated in **Steps 42** and **50**?

54. Turn the circuit switch to the "off" position.
55. Disconnect the circuit.
56. Turn off the multimeter, and disconnect the probes from the multimeter.

## Questions

1. What happens to total voltage in a series circuit when more voltage sources are added to it?

2. What happens to total resistance in a series circuit when more resistance sources are added to it?

3. How does the sum of the voltage drops across the resistors in a series circuit compare with the total applied voltage in the circuit?

## Evaluation

Evaluation is based on your ability to calculate electrical property values of a series circuit. You will also be evaluated on your ability to safely construct and test simple series circuits.

(2 DAYS)

# PARALLEL RESISTIVE CIRCUITS

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**Essential Elements:** Common: 6A, 6B, 8C, 9A, 9B
Specific: 1, 2, 3, 9
**TAAS Objectives:** Mathematics: C 1, 2, 4; O 1, 3, 4
Language Arts: RC 4, 5; WC 1

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## Activity Summary

This activity is designed to provide students with the opportunity to calculate the voltage, current, and resistance values of parallel circuits. Students will also be given the opportunity to measure the voltage, current, and resistance values of parallel circuits using the voltmeter, milliammeter, and ohmmeter functions of a multimeter. This activity will also enable the student to understand the use of metric prefixes in electrical calculations and measurements.

## Teaching Tips

1. Read through the activity before beginning.
2. Reproduce activity sheets for each student, or lab group, before the activity.
3. Organize all equipment and supplies before the activity.
4. Students should construct and test the two-resistor parallel circuit on the first day, and construct and test the three-resistor parallel circuit on the second day.

## Instructional Strategy

- Explain and demonstrate the relationship between the electrical properties of voltage, current, and resistance in a parallel circuit.
- Explain and demonstrate the use of metric prefixes to abbreviate values of voltage, current, and resistance.
- Explain and demonstrate the use of symbols for electrical components and the use of schematic diagrams to represent electrical circuits.
- Explain and demonstrate the construction of parallel circuits on a proto-board.
- Explain and demonstrate the use of the voltmeter function of a multimeter.
- Explain and demonstrate the use of the milliammeter function of a multimeter.
- Explain and demonstrate the use of the ohmmeter function of a multimeter.

## Equipment/Supplies

1. 6-volt lantern battery
2. Proto-board with connecting wires
3. Single-pole slide switch
4. 1/2-watt carbon composition resistors of various resistance values
5. Analog, or digital, multimeter with test probes
6. Calculator

## Evaluation Key

1. Instructor evaluation of student's ability to calculate voltage, current, and resistance values of parallel circuits.
2. Instructor evaluation of student's ability to interpret schematic diagrams for parallel circuits.
3. Instructor evaluation of student's ability to construct parallel circuits.

4. Instructor evaluation of student's ability to interpret Resistor Color Code information on each resistor.
5. Instructor evaluation of student's ability to measure voltage values with the voltmeter function of a multimeter.
6. Instructor evaluation of student's ability to measure current values with the milliammeter function of a multimeter.
7. Instructor evaluation of student's ability to measure the resistance value of each resistor using the ohmmeter function of a multimeter.
8. Instructor evaluation of student's ability to follow safety guidelines established for test equipment and circuit evaluation.
9. Instructor evaluation of student's ability to follow the procedures of the activity sheet.
10. Instructor evaluation of student's ability to interpret metric prefix measurements.

# PARALLEL RESISTIVE CIRCUITS

*Experiment with parallel circuit calculations, construction, and testing.*

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## Objectives

- To construct parallel circuits following a schematic diagram
- To identify voltage, current, and resistance characteristics of parallel circuits
- To calculate unknown electrical properties for parallel circuits
- To measure the value of electrical properties of parallel circuits using the different functions of a multimeter.

## Vocabulary/Concepts Reinforced

- Parallel circuit
- Voltage
- Current
- Resistance
- Resistor
- Multimeter
- Voltmeter
- Milliammeter
- Ohmmeter

## Equipment/Supplies

- 6-volt lantern battery
- Proto-board with connecting wires
- Single-pole slide switch
- 1/2-watt carbon composition resistors of various resistance values
- Analog, or digital, multimeter with test probes
- Calculator

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## Introduction

A parallel circuit provides two, or more, paths for current flow. The loads of a parallel circuit are connected across the leads of the power source to form "branches." Current flow through each branch of a parallel circuit is independent of the current flow through the other branches. A break in current flow in one branch of a parallel circuit does not prevent current from flowing in the other branches of the circuit. Parallel circuit connections are also known as "shunt" connections.

The voltage applied to a parallel circuit is the same across all the branches of the circuit. All the loads of a parallel circuit must be designed to operate at the same voltage.

The total current in a parallel circuit is divided among the branches of the circuit. Total current in a parallel circuit will increase as more branches are added to the circuit. The total current flow through a parallel circuit is equal to the sum of the current flow through the resistive loads of each branch of the circuit. This statement can be expressed mathematically with the following equation.

$$L_T = I_{\text{branch 1}} + I_{\text{branch 2}} + I_{\text{branch 3}} \cdots + I_{\text{branch (n)}}$$

$I_T$ = total current

$I_{\text{branch (n)}}$ = number of parallel branches

The total resistance of a parallel circuit decreases as more branches are added to the circuit. The total resistance of a parallel circuit is always less than the resistance value of any branch in the circuit. The total resistance of a parallel circuit can be calculated by using one of the following equations.

If there are two resistors of different values connected in parallel, the following equation is used to calculate the total resistance of the circuit.

$$R_T = \frac{R_1 \cdot R_2}{R_1 + R_2}$$

If there are two, or more, resistors of the same value connected in parallel, the following equation is used to calculate the total resistance of the circuit.

$$R_T = \frac{\text{Value of one resistor}}{\text{Number of resistors}}$$

If there are three, or more, resistors of different values connected in parallel, the following equation is used to calculate the total resistance of the circuit.

$$R_T = \frac{1}{\frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3} + \frac{1}{R_{(n)}}}$$

In the parallel circuits for this activity, the current level will be very low. To abbreviate the decimal number values for current, the metric prefixes *milli* and *micro* are used. The metric prefix milli represents 0.001. Many current flow values are measured in milliamperes. One milliampere of current flow is equal to 0.001 ampere. The metric prefix micro represents 0.000001. Very small amounts of current flow ware measured in microamperes. One microampere of current flow is equal to 0.000001 ampere.

The resistance value of the resistors for this activity may be quite large. To abbreviate the large number values for resistance, the metric prefixes kilo and Mega are used. The metric prefix kilo represents 1,000. Many resistance values are measured in kilohms. One kilohm of resistance is equal to 1,000 ohms. The metric prefix Mega represents 1,000,000. Very large amounts of resistance are measured in megohms. One megohm of resistance is equal to 1,000,000 ohms.

Metric prefixes are widely used to abbreviate very small or very large number values for electrical property units. The metric prefix units cannot be used in an equation. When using numbers in calculations, the base units of volts, amperes, and ohms must be used.

The Ohm's law equations for calculating current and voltage must be used in this activity. The following abbreviations are used in Ohm's law equations.

E or V = voltage
I = current
R = resistance

The Ohm's law equation for voltage indicates that the voltage applied to a circuit is equal to the product of the circuit current and the circuit resistance.

$$E = I \cdot R$$

The Ohm's law equation for current indicates that the amount of current in a circuit is equal to the voltage applied to the circuit divided by the resistance of the circuit.

$$I = \frac{E}{R}$$

This activity will demonstrate the construction of parallel circuits from a schematic diagram. A battery will be used as the power source for the parallel circuits in the activity, and carbon composition resistors are used as the loads in the circuit. The parallel circuits will be tested for voltage, current, and resistance characteristics with the appropriate functions of the multimeter.

**Procedure**

1. Locate the 6-volt lantern battery, proto-board, connecting wire, single-pole switch, 1/2-watt carbon composition resistors, and multimeter with test probes.
2. Choose two resistors, and calculate the resistance value of each resistor using the Resistor Color Code.

$R_1$= ________________ohms
$R_1$= ________________kilohms
$R_2$= ________________ohms
$R_2$= ________________kilohms

3. Place the red test probe into the positive terminal of the multimeter.
4. Place the black test probe into the negative terminal of the multimeter.
5. Set the multimeter to the proper ohmmeter range, and measure the resistance value of $R_1$.

$R_1$ =________________kilohms
$R_1$ =________________ohms

6. Set the multimeter to the proper ohmmeter range, and measure the resistance value of $R_2$.

$R_2$ =________________kilohms
$R_2$ =________________ohms

7. Construct the circuit drawn in Figure 1. The circuit switch should be in the "off" position.
8. Calculate the total resistance of the circuit using the measured values for $R_1$ and $R_2$ found in **Steps 5** and **6**.

$$R_T = \frac{R_1 \cdot R_2}{R_1 + R_2}$$

$R_T$ = ________________ohms
$R_T$ = ________________kilohms

9. How does the calculated value of total resistance compare with the value of each resistor in the circuit?

10. Set the multimeter to the proper ohmmeter range to measure total resistance in the circuit.
11. Measure and record the value of total resistance in the circuit by connecting the probes of the multimeter to **Test Points E** and **F**, or **Test Points C** and **G**.

$R_T$ = ________________kilohms
$R_T$ = ________________ohms

12. How does the measured value of total resistance compare with the calculated value of total resistance?

13. Turn the circuit switch to the "on" position.
14. Set the multimeter to the proper voltmeter range to measure the voltage produced by the lantern battery.
15. Measure and record the value of voltage produced by the lantern battery by connecting the probes of the multimeter to **Test Points A** and **B**.

$V_T$ =________________volts

16. Measure and record the voltage across $R_1$ by connecting the probes of the multimeter to **Test Points C** and **G**.

$V_{R_1}$ =________________volts

17. Measure and record the voltage across $R_2$ by connecting the probes of the multimeter to **Test Points E** and **F**.

$V_{R_2}=$________________volts

18. How does the total voltage compare with the voltage across $R_1$ and $R_2$?

19. Turn the circuit switch to the "off" position.
20. Calculate the current flow in the circuit, using the voltage value measured in **Step 15** and the resistance value measured in **Step 11**.

$$I_T = \frac{E_T}{R_T}$$

$I_T =$________________amperes
$I_T =$________________milliamperes

21. Set the multimeter to the proper milliammeter range to measure the current flow through the circuit.
22. Disconnect the wire at **Test Points B** and C, and place the probes of the multimeter in the circuit at **Test Points B** and C. (Observe polarity.)
23. Turn the circuit switch to the "on" position. Record the value of current flow in the circuit.

$I_T =$________________milliamperes
$I_T =$________________amperes

24. Turn the circuit switch to the "off" position, and reconnect the wire at **Test Points B** and C.
25. How does the calculate value of current flow in the circuit compare with the measured value of current flow in the circuit ?

26. Calculate the current flow through the branch of the circuit containing $R_1$, using the voltage value measured in **Step 16** and the resistance value measured in **Step 5**.

$$I_{R_1} = \frac{E_{R_1}}{R_1}$$

$I_{R_1} =$________________amperes

$I_{R_1}$ =_______________milliamperes

27. Set the multimeter to the proper milliammeter range to measure the current flow through $R_1$.
28. Disconnect the wire at **Test Points C** and **D**, and place the probes of the multimeter in the circuit at **Test Points C** and **D**. (Observe polarity.)
29. Turn the circuit switch to the "on" position. Record the value of current flow through $R_1$.

$I_{R_1}$ =_______________milliamperes

$I_{R_1}$ =_______________amperes

30. Turn the circuit switch to the "off" position, and reconnect the wire at **Test Points C** and **D**.
31. How does the calculated value of current flow through $R_1$ compare with the measured value of current flow through $R_1$?

32. Calculate the current flow through the branch of the circuit containing $R_2$, using the voltage measured in **Step 6**.

$$I_{R_2} = \frac{E_{R_2}}{R_2}$$

$I_{R_2}$ =_______________amperes

$I_{R_2}$ =_______________milliamperes

33. Set the multimeter to the proper milliammeter range to measure the current flow through $R_2$.
34. Disconnect the wire at **Test Points C** and **E**, and place the probes of the multimeter in the circuit at **Test Points C** and **E**. (Observe polarity.)
35. Turn the circuit switch to the "on" position. Record the value of current flow through $R_2$.

$I_{R_2}$ =_______________milliamperes

$I_{R_2}$ =_______________amperes

36. Turn the circuit switch to the "off" position, and reconnect the wire at **Test Points C** and **E**.

38. Add the value of current through $R_1$ measured in **Step 29** to the current value through $R_2$ measured in **Step 35**.

39. How does the sum of the current flow through $R_1$ and $R_2$ compare with the value of total current measured in **Step 23**?

40. Locate another resistor. This resistor will represent $R_3$ in Figure 2.

41. Calculate the resistance value of the resistor using the Resistor Color Code.

$R_3$ = ________________ohms
$R_3$ = ________________kilohms

42. Set the multimeter to the proper ohmmeter range to measure the resistance value of $R_3$.

$R_3$ = ________________kilohms
$R_3$ = ________________ohms

43. Add $R_3$ to the circuit to form the circuit shown in Figure 2.

44. Calculate the total resistance of the circuit using the measured values for $R_1$, $R_2$, and $R_3$ found in **Steps 5, 6,** and **42**.

$$R_T = \frac{1}{\frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3}}$$

$R_T$ = ________________ohms
$R_T$ = ________________kilohms

45. How does the calculated value of total resistance compare with the value of each resistor in the circuit?

46. Set the multimeter to the proper ohmmeter range to measure total resistance in the circuit.

47. Measure and record the value of total resistance in the circuit by connecting the probes of the multimeter to **Test Points G and H**.

$R_T$ = ________________kilohms
$R_T$ = ________________ohms

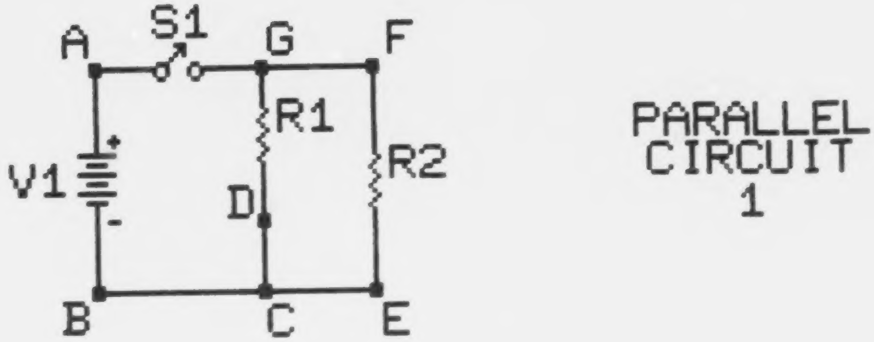
A
S1
G
F
R1
R2
V1
+
-
D
B
C
E
PARALLEL
CIRCUIT
1

Figure 1

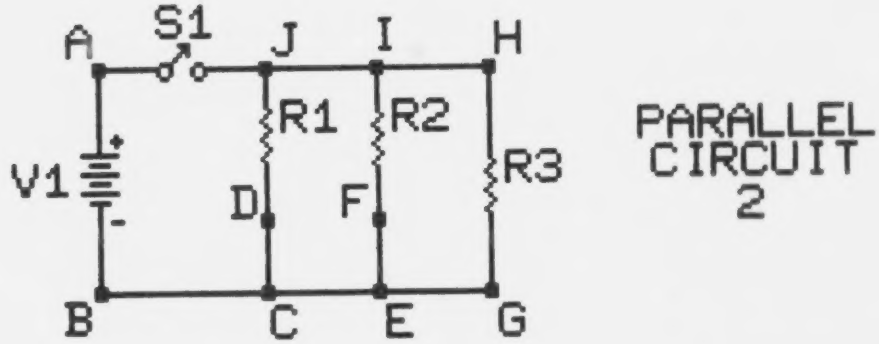
A
S1
J
I
H
R1
R2
R3
V1
+
-
D
F
B
C
E
G
PARALLEL
CIRCUIT
2

Figure 2

48. How does the measured value of total resistance compare with the calculated value of total resistance?

49. Turn the circuit switch to the "on" position.
50. Set the multimeter to the proper voltmeter range to measure the voltage produced by the lantern battery.
51. Measure and record the value of voltage produced by the lantern battery by connecting the probes of the multimeter to **Test Points A and B**.

$V_T$ = ______________volts

52. Measure and record the voltage across $R_1$ by connecting the probes of the multimeter to **Test Points C** and **J**.

$V_{R_1}$ = ______________volts

53. Measure and record the voltage across $R_2$ by connecting the probes of the multimeter to **Test Points E** and **I**.

$V_{R_2}$ = ______________volts

54. Measure and record the voltage across $R_3$ by connecting the probes of the multimeter to **Test Points G** and **H**.

$V_{R_3}$ = ______________volts

55. How does the total voltage compare with the voltage across $R_1$, $R_2$, and $R_3$?

56. Turn the circuit switch to the "off" position.
57 Calculate the current flow in the circuit, using the voltage value measured in **Step 51** and the resistance value measured in **Step 47**.

$$I_T = \frac{E_T}{R_T}$$

$I_T$ =______________amperes

$I_T$ =______________milliamperes

58. Set the multimeter to the proper milliammeter range to measure the current flow through the circuit.
59. Disconnect the wire at **Test Points B and C,** and place the probes of the multimeter in the circuit at **Test Points B** and **C**. (Observe polarity.)
60. Turn the circuit switch to the "on" position. Record the value of current flow in the circuit.

$I_T$ =________________milliamperes

$I_T$ =________________amperes

61. Turn the circuit switch to the "off" position, and reconnect the wire at **Test Points B** and C.

62. How does the calculated value of current flow in the circuit compare with the measured value of current flow in the circuit?

63. Calculate the current flow through the branch of the circuit containing $R_1$, using the voltage value measured in **Step 52** and the resistance value measured in **Step 5**.

$$I_{R_1} = \frac{E_{R_1}}{R_1}$$

$I_{R_1}$ =________________amperes

$I_{R_1}$ =________________milliamperes

64. Set the multimeter to the proper milliammeter range to measure the current flow through $R_1$.
65. Disconnect the wire at **Test Points C** and **D**, and place the probes of the multimeter in the circuit at **Test Points C** and **D**. (Observe polarity.)
66. Turn the circuit switch to the "on" position. Record the value of current flow through $R_1$.

$I_{R_1}$ =________________milliamperes

$I_{R_1}$ =________________amperes

67. Turn the circuit switch to the"off" position, and reconnect the wire at **Test Points C and D.**
68. How does the calculated value of current flow through $R_1$ compare with the measured value of current flow through $R_1$?

69. Calculate the current flow through the branch of the circuit containing $R_2$, using the voltage value measured in **Step 53** and the resistance value measured in **Step 6**.

$$E_{R_2}$$

$I_{R_2} = R_2$

$I_{R_2}$ =________________amperes

$I_{R_2}$ =________________milliamperes

70. Set the multimeter to the proper milliammeter range to measure the current flow through $R_2$.
71. Disconnect the wire at **Test Points E** and **F**, and place the probes of the multimeter in the circuit at **Test Points E** and **F**. (Observe polarity.)
72. Turn the circuit switch to the "on" position. Record the value of current flow through $R_2$.

$I_{R_2}$ =________________milliamperes

$I_{R_2}$ =________________amperes

73. Turn the circuit switch to the"off" position, and reconnect the wire at **Test Points E** and **F**.
74. How does the calculated value of current flow through $R_2$ compare with the measured value of current flow through $R_2$?

75. Calculate the current flow through the branch of the circuit containing $R_3$, using the voltage value measured in **Step 54** and the resistance value measured in **Step 42**.

$$I_{R_3} = \frac{E_{R_3}}{R_3}$$

$I_{R_3}$ =________________amperes

$I_{R_3}$ =________________milliamperes

76. Set the multimeter to the proper milliammeter range to measure the current flow through $R_3$.
77. Disconnect the wire at **Test Points G** and **H**, and place the probes of the multimeter in the circuit at **Test Points G** and **H**. (Observe polarity.)
78. Turn the circuit switch to the "on" position. Record the value of current flow through $R_3$.

$I_{R_3}$ =________________milliamperes

$I_{R_3}$ =________________amperes

79. Turn the circuit switch to the "off" position, and reconnect the wire at **Test Points G and H.**
80. How does the calculated value of current flow through $R_3$ compare with the measured value of current flow through $R_3$?

81. Add the values of current flow through $R_1$, $R_2$, and $R_3$ measured in **Steps 66, 72, and 78.**
82. How does the sum of the current flow through $R_1$, $R_2$, and $R_3$ compare with the value of total current measured in **Step 60**?

83. How does the total current measured in this circuit in **Step 60** compare with the total current measured in the first circuit in **Step 23**?
84. Disconnect the components from the proto-board.
85. Turn off the multimeter, and disconnect the test probes.

## Questions

1. What happens to total resistance in a parallel circuit when more resistive sources are added to it?

2. What happens to total current in a parallel circuit when more resistive sources are added to it?

3. How does the total applied voltage in a parallel circuit compare with the voltage across each branch of the parallel circuit?

## Evaluation

Evaluation is based on your ability to calculate electrical property values of parallel circuits. You will also be evaluated on your ability to safely construct and test parallel circuits.

# ELECTRONIC SCHEMATICS

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**Essential Elements:** Common: 8-10
Specific: 1, 2, 6, 9, 11, 12
**TAAS Objectives:** Mathematics: C 1, 2, 4; O 1, 3, 4
Language Arts: RC 4, 5; WC 1

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### Activity Summary

This activity is intended to give students some relevance to the use of graphic communication in today's high-tech electronics industries. This student activity seeks to associate this relevance with the more sophisticated means for power and communications transmission and their uses.

### Teaching Tips

Because students and others are often baffled by the seemingly complex application of electronic components in electronic gadgetry and their graphic representation:

1. Let the student know that though a basic knowledge of electronics would be useful for this activity, it is not essential. (Nor does the teacher need a background in electronics to be successful.)
2. The exercises should be pursued with the symbols being considered generic in nature. In-depth relevance of these symbols to electronics should be made after the exercises are completed. (Treat the problems as graphic puzzles.)
3. The follow-up should include student exposure to electronic terms and identification of electronic component devices.

### Instructional Strategy

- As introductory problems, rely on "fill-in" component symbol diagrams provided in text books. Let student sketch/draw one or more of these problems before introduction them to the "conceptual" approach to schematic development.
- Show them actual electronic component parts, and compare them to their symbolic graphic representation.
- Following the example(s) provided, prepare your own "conceptual" idea problems/exercises from schematic drawings previously drawn by students or from actual schematics accompanying simple electronic gadgets like remote control units, amplifiers, transistor radios receivers or calculators, etc.

### Equipment/Supplies

1. Prepared (elementary) schematic diagram problems
2. Teacher-developed field note problems derived from elementary schematic diagrams
3. Templates: Electronic component device templates, Timesaver #404 and Rapid Design #404

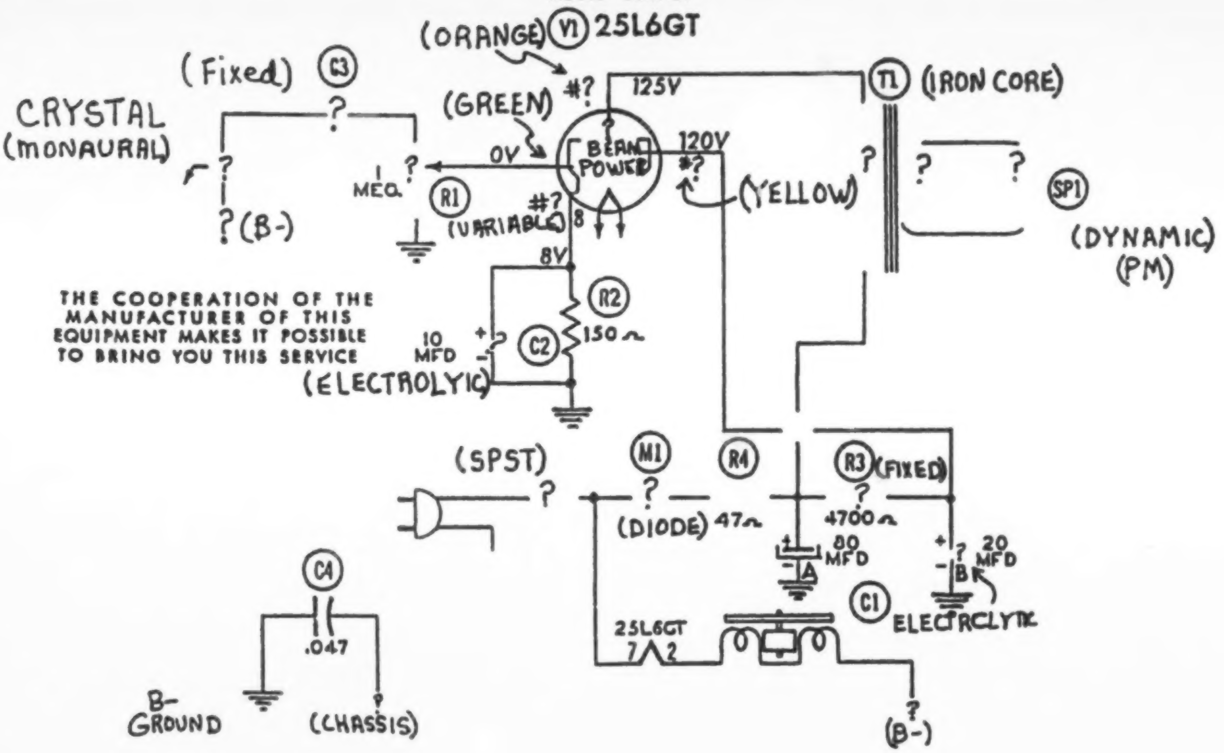
### Evaluation Key

1. The schematic diagram, sometimes called the *elementary* diagram, is the primary design drawing of the electronics industry. It shows the functions and relations of the component devices of a circuit by means of graphic symbols; it does not show the physical relationship of those components, however. Professionally prepared schematics are easily understood by persons schooled in electronics to trace circuitry, to design and analyze circuits, for instructional purposes and for troubleshooting.

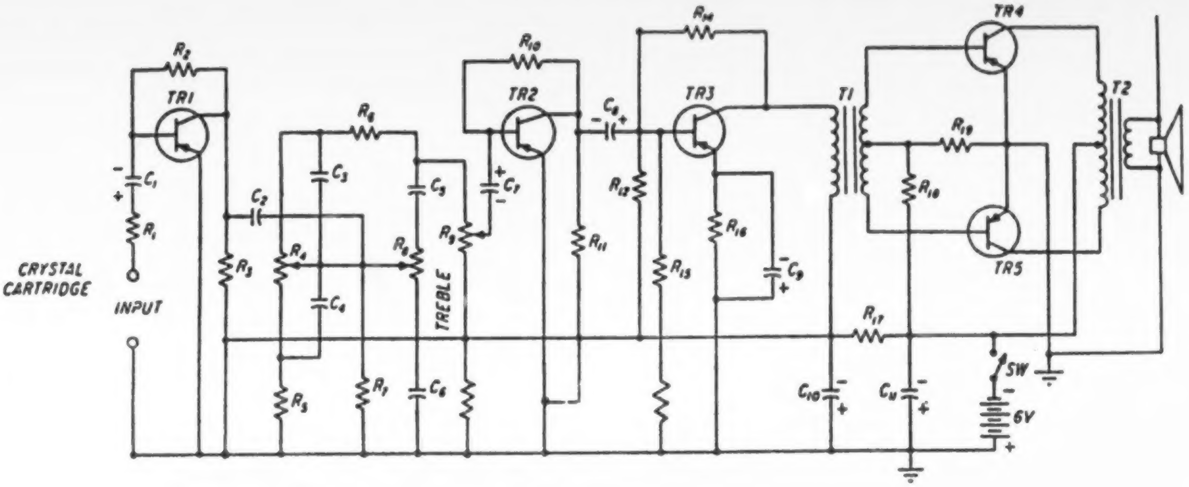
2. The purpose of an electronic component device symbol is to provide a way to graphically represent the "likes" of the actual component device in an electronic circuit.
3. Reference designators include certain standard abbreviations and prefixes of electronic components. The combination letters/numbers identify the kind of components and its numerical order in the schematic.
4. One (the major) organization that publishes the guidelines for graphic symbols, designators, and drafting practices is the American National Standards Institute, e.g., 76-ANSI/IEEE (Institute of Electrical and Electronics Engineers, Inc.) Y32E.
5. Schematic diagrams are "built" basically from left (power source/subassembly connection) to the right and from the top of the drawing page down.
6. Development of a new electronic product depends on the conceptualized design approach of an engineer's/project chief's sketch of circuitry. This conceptual level of problem solution equates fundamental layout of an elementary (schematic) diagram, is usually very rough, and requires considerable refinement. The drafter/CAD operator then produces a sound, well-balanced and pleasing to the eye drawing that may include minor to perhaps major changes in configuration (reorientation of symbols and redirection of lines) while still maintaining original technical significance. Simplicity and clarity are major considerations.
7. The "conceptual" approach herein used for the development of an electronic product is a teaching strategy to place the student in a design engineer's or project chief's position and to facilitate the conceptual level or circuit design. The problem-solving stage is done by the sketching process. The "idea notes" simulate what might be going on in the engineer's/project chief's mind at the onset of product conception.

### Support Materials

1. Baer, Charles J., and Ottaway, John R. *Electrical and Electronics Drawing*. 4th ed. Dallas: Gregg Division, McGraw-Hill, 1980. See chapter 6, pp. 164-208.
2. Currently adopted texts


AUDIO OUTPUT
(ORANGE) V1 25L6GT
(Fixed) C3
CRYSTAL (MONAURAL)
?
? (B-)
1 MEG. ?
R1
#? (VARIABLE) 8
(GREEN)
#?
125V
0V
BEAM POWER
120V
#?
(YELLOW)
T1 (IRON CORE)
? ? ?
SP1
(DYNAMIC) (PM)
8V
R2
150 Ω
10 MFD
C2
(ELECTROLYTIC)
(SPST)
?
M1
?
(DIODE)
R4
47 Ω
R3 (FIXED)
?
4700 Ω
80 MFD
A
20 MFD
B
C1
ELECTROLYTIC
25L6GT
7 2
C4
.047
B- GROUND
(CHASSIS)
(B-)

THE COOPERATION OF THE MANUFACTURER OF THIS EQUIPMENT MAKES IT POSSIBLE TO BRING YOU THIS SERVICE


TR1
R2
C1
R1
CRYSTAL CARTRIDGE
INPUT
C2
R3
R4
R5
C3
C4
R6
R7
C5
R8
C6
TREBLE
R9
C7
R10
TR2
R11
C8
R14
TR3
R12
R13
R15
R16
C9
T1
R19
R18
R17
C10
C11
SW
6V
TR4
TR5
T2

$R_1$ — 10,000 OHMS
$R_2$ — 150,000 OHMS
$R_3$ — 6800 OHMS
$R_4$ — 50,000 OHMS LINEAR BASS
$R_5$ — 1000 OHMS
$R_6$ — 10,000 OHMS
$R_7$ — 100,000 OHMS

$R_8$ — 50,000 OHMS LINEAR
$R_9$ — 10,000 OHMS TAPER AUDIO V.C.
$R_{10}$ — 220,000 OHMS
$R_{11}$ — 2200 OHMS
$R_{12}$ — 4700 OHMS
$R_{13}$ — 33,000 OHMS
$R_{14}$ — 47,000 OHMS

ALL RESISTORS 1/2 W

$R_{15}$ — 1500 OHMS
$R_{16}$ — 330 OHMS
$R_{17}$ — 220 OHMS
$R_{18}$ — 1200 OHMS
$R_{19}$ — 33 OHMS
$TR_1$, $TR_2$, $TR_3$ — GE 2N321
$TR_4$, $TR_5$ — GE 2N382

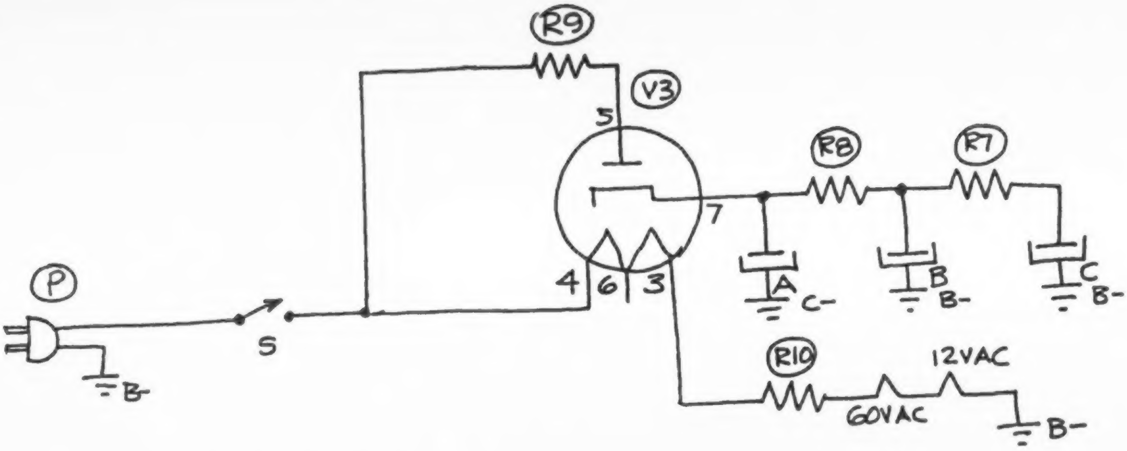
$C_1$ — 8 mfd 6V
$C_2$ — .50 mfd
$C_3$ — .02 mfd
$C_4$ — .20 mfd
$C_5$ — .005 mfd
$C_6$ — .10 mfd
$C_7$ — 10 mfd 6V

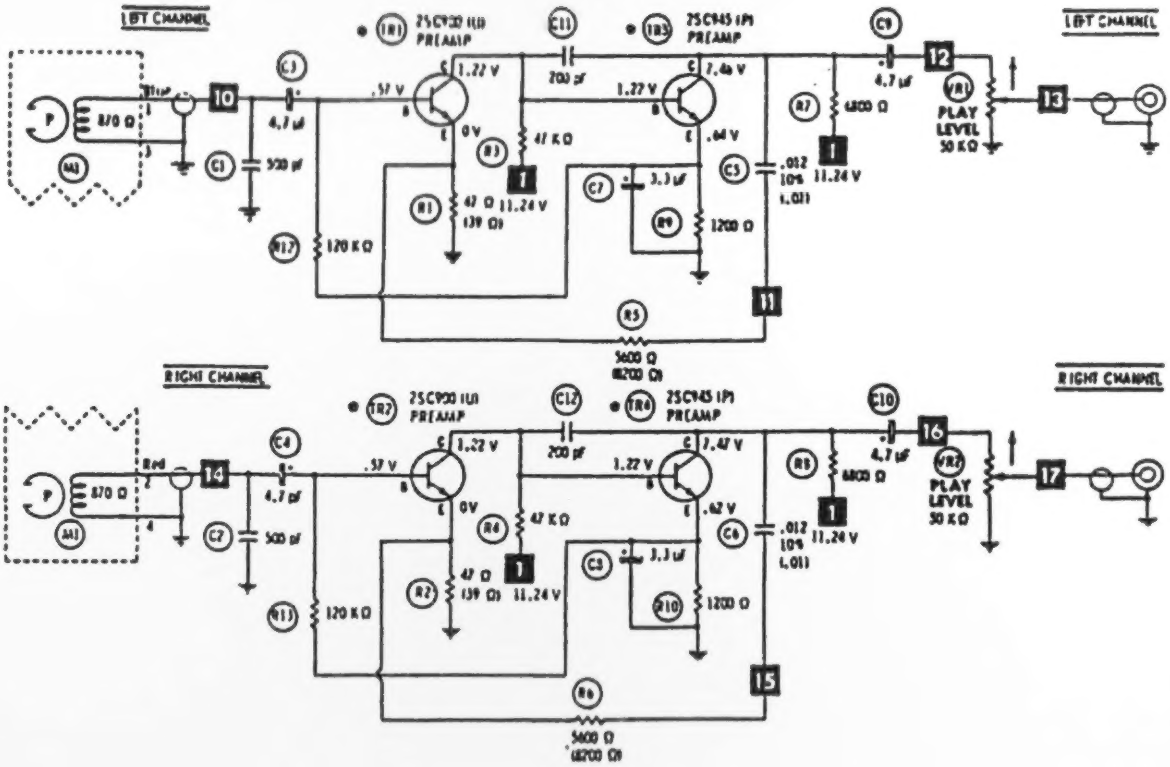
$C_8$ — 10 mfd 6V
$C_9$ — 50 mfd 6V
$C_{10}$ — 50 mfd 6V
$C_{11}$ — 50 mfd 6V
$T_1$ — 2K/1.5K CT
$T_2$ — 100Ω C.T/V.C.

PERFORMANCE DATA:

MAXIMUM POWER OUTPUT @ 10% DISTORTION — 300 MW

DISTORTION AT 100 MILLIWATTS:
60 Hz — 3.0%
1000 Hz — 1.5%
5000 Hz — 3.0%


R9
V3
5
R8
R7
7
P
4
6
3
A
C-
B
B-
C
B-
S
B-
R10
12VAC
60VAC
B-


LEFT CHANNEL
TR1
2SC900 (U)
PREAMP
C11
200 pf
TR3
2SC945 (P)
PREAMP
C9
LEFT CHANNEL
M1
P
870 Ω
Blue
1
3
10
C3
4.7 µf
C1
500 pf
.57 V
B
C
1.22 V
E
0 V
R3
47 KΩ
1
11.24 V
R1
47 Ω
(39 Ω)
R12
120 KΩ
1.22 V
7.46 V
.64 V
C7
3.3 µf
R9
1200 Ω
C5
.012
10%
(.01)
R7
6800 Ω
1
11.24 V
4.7 µf
12
VR1
PLAY
LEVEL
50 KΩ
13
11
R5
5600 Ω
(8200 Ω)
RIGHT CHANNEL
TR2
2SC900 (U)
PREAMP
C12
200 pf
TR4
2SC945 (P)
PREAMP
C10
RIGHT CHANNEL
M1
P
870 Ω
Red
2
4
14
C4
4.7 µf
C2
500 pf
.57 V
B
C
1.22 V
E
0 V
R4
47 KΩ
1
11.24 V
R2
47 Ω
(39 Ω)
R13
120 KΩ
1.22 V
7.47 V
.62 V
C8
3.3 µf
R10
1200 Ω
C6
.012
10%
(.01)
R8
6800 Ω
1
11.24 V
4.7 µf
16
VR2
PLAY
LEVEL
50 KΩ
17
15
R6
5600 Ω
(8200 Ω)

# ELECTRONIC SCHEMATICS

*Learn fundamental identification of electronic component symbols.*

## Objectives

- To identify basic ANSI electronic component/device symbols and their approved reference designators, and to note properly their respective descriptors
- To sketch and/or use templates to properly place component device symbols into an elementary schematic diagram
- To use conceptual level engineer/project chief "ideas" in preparing a sketch/drawing of an elementary electronics schematic diagram

## Vocabulary/Concepts Reinforced

- Schematic diagram—a graphic representation of electronic component device arrangement to serve as means for understanding/servicing of electronic circuitry
- Electronic component symbol—the American National Standards graphic representation of electronic devices (components) that make up electronic printed or solid state circuitry
- American National Standards—industrial/governmental approved graphic symbols and reference designators published under American National Standards Institute (ANSI) guidelines

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## Procedure

*Problem A*

Examples 1 and 2 (introduction to electronic symbols) packet includes a basic schematic with space (blanks) for component symbols, parts list including reference designators/descriptors (name and size) and a graphic symbols "catalog" (example provided).

1. According to the given reference designator, identify the type of component, using the parts list provided.
2. Select the symbol for each of the electronic components, using the component symbol catalog provided.
3. Within a prepared (copied) schematic diagram (problem), sketch in appropriate symbols in the available spaces.
4. On drawing paper, make a double-size drawing of your problem solution.
    a. Lightly draw out the given schematic diagram without the component symbols in place.
    b. Using a component symbol template, properly orientate the symbol to the diagram and draw in place (draw them to finished line weight—H lead).
    c. Darken schematic arrangement.
    d. Add reference designators and descriptors. Use appropriate-sized lettering as prescribed by your text or your instructor.

*Problem B*

Examples 1 and 2 (Designing/arranging a basic electronic schematic diagram). The problem is presented in the form of "conceptual notes" with each component listed generally in the order in which it is to be added to the diagram. (Follow the outline below to determine the placement for each component symbol.)

Reference designator—Component symbol—Connected to what prior component symbol—By what wire leads or pins (color)

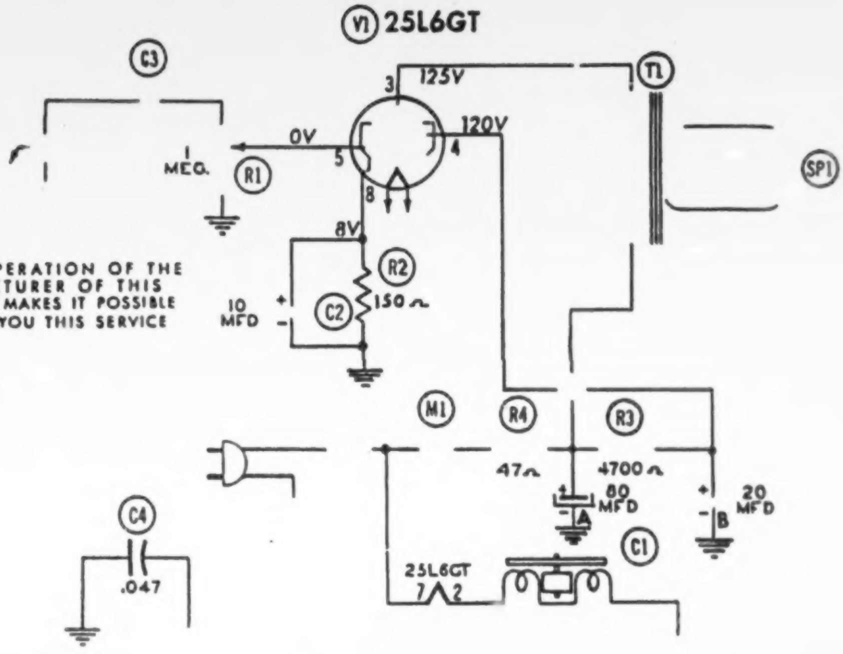
(Two sample problems are provided along with a key to the solution and an example of student's effort.) As one would build a "chain," each component symbol is added to the diagram starting at the left of the drawing page and working to the right and *basically* from the top of the page, down. (The solution should be in the form of a sketch with an instrument drawing being done later.)

1. Sketch first component (power source) or subassembly connector.
2. Sketch in second component. Its placement/connection is determined by instructions given in column "connect to." (Draw schematic line(s) back to prior component, e.g. #1. This component will, in turn, be connected to additional component(s) in a sequential order.)
3. Sketch additional components in position by determining their link-up with prior and succeeding components identified under the column "connect to."
4. In the event a component has two or more connecting pins (leads), e.g., transistors, the connecting point(s) are designated under "lead."
   *Note*: The component symbol provided in the form of conceptual idea notes must be inserted into the schematic diagram in accordance with its presented orientation. The symbol is not to be turned around in any way.
5. Check your solution against the key supplied by your teacher. Correct your solution.
6. If instructed to do so, make an instrument drawing of this schematic by using the *key* schematic (copy). Determine an appropriate scale to enlarge or reduce the original (depending on the assigned sheet size). This will reflect corrections to your sketch attempt from the engineer's/project chief's conceptual notes.

## Evaluation

1. What is an electronic schematic diagram?
2. What is the purpose of an electronic component device symbol?
3. What are reference designators?
4. What organization publishes guidelines for industrial/government approved graphic symbols, component designators, and electronic drafting practices?
5. Schematic diagrams of electronic component devices are basically "built" from __________ to __________ and from the __________ of the drawing page __________.
6. Explain the conceptualized order of circuit development from the design engineer's/project chief's ideas/thoughts to the finished drawing produced by the drafter/CAD operator.
7. Explain the "conceptual" development approach used in this activity to facilitate circuit design for an electronic product.

THE COOPERATION OF THE MANUFACTURER OF THIS EQUIPMENT MAKES IT POSSIBLE TO BRING YOU THIS SERVICE


V1 25L6GT
C3
125V
T1
0V
120V
1 MEG.
R1
5
4
3
8
SP1
8V
R2
150 Ω
10 MFD
C2
M1
R4
R3
47Ω
4700Ω
80 MFD
A
20 MFD
B
C4
C1
.047
25L6GT
7 2

---

## PARTS LIST AND DESCRIPTIONS

### TUBES

| Item No. | USE |
|---|---|
| V1 | Audio Output |

### CAPACITORS

| Item No. | RATING | | NOTES |
|---|---|---|---|
| | CAP. | VOLT | |
| C1A | 80 | 150 | Red |
| B | 20 | 150 | Blue |
| C2 | 10 | 25 | |
| C3 | .001 | 600 | |
| C4 | .047 | 400 | |

### CONTROLS

| Item No. | RATING | | INSTALLATION NOTES |
|---|---|---|---|
| | RESIST-ANCE | WATTS | |
| R1A | 1 Meg | 1/2 | Volume |
| B | Shaft | | Attach to R1A |
| C | Switch | | Attach to R1A |

### RESISTORS

| Item No. | RATING | | NOTES |
|---|---|---|---|
| | OHMS | WATTS | |
| R2 | 150Ω | 1/2 | |
| R3 | 4700Ω | 1/2 | |
| R4 | 47Ω | 1/2 | |

### TRANSFORMER (AUDIO OUTPUT)

| Item No. | RATING | | | |
|---|---|---|---|---|
| | IMPEDANCE | | DC RES. | |
| | PRI. | SEC. | PRI. | SEC. |
| T1 | 2.1KΩ | 3.4Ω | 168Ω | .57Ω |

### SPEAKER

| Item No. | RATING | | |
|---|---|---|---|
| | SIZE | FIELD | V.C. IMP |
| SP1 | 4" | PM | 3.4Ω |

### SELENIUM RECTIFIER

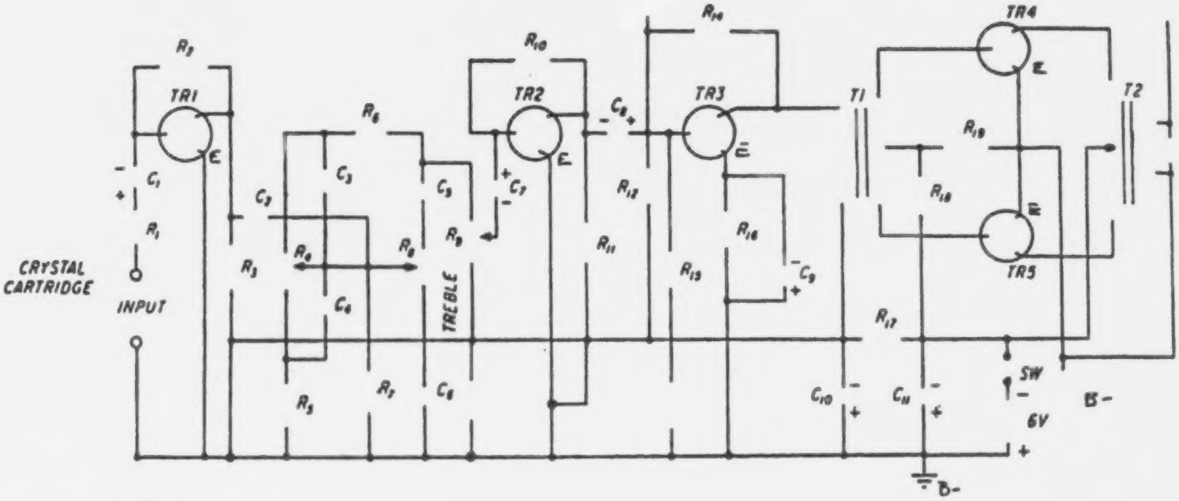
| Item No. | RATING |
|---|---|
| | CURRENT |
| M1 | .053 A |

### PHONO CARTRIDGE

| Item No. | REMARKS |
|---|---|
| M2 | Tone Arm |

### PHONO NEEDLE

| Item No. |
|---|
| M3 |

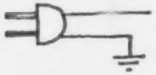
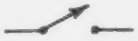
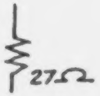
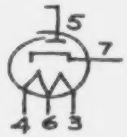
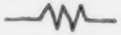
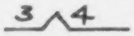
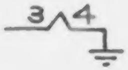
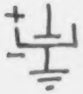

R2
TR1
E
C1
R1
CRYSTAL CARTRIDGE
INPUT
R3
C2
R6
C3
C5
R4
R8
R9
C4
TREBLE
R5
R7
C6
R10
TR2
E
C7
R11
C8
R14
TR3
E
R12
R13
R16
C9
T1
C10
R17
C11
R19
R18
TR4
E
TR5
E
T2
SW
6V
B-
B-

## Problem A, Example 2

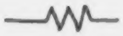
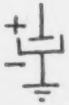
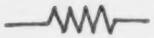
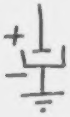
Instructions: Using the information provided above and the electronic symbols description catalog, complete the elementary schematic diagram by sketching in the appropriate component symbols.

Problem B. Example 1

Instructions: Using the "field notes" below, and starting at the left side of your work page, arrange (sketch) the given components within a schematic framework exemplified by those problems presented in Problem A above. (Examples A and B.)

| Ref. Designator | Component Symbol | Connect to | Leads (pin) |
|---|---|---|---|
| A (POWER SOURCE) |  | SWITCH | |
| S (SWITCH) |  | & A<br>R9 | |
| R9 (RESISTOR) |  | V3 & | 5<br>4 |
| V3 (RECT. PHOTOTUBE) |  | R9<br>S<br>R10<br>R8 | 5<br>4<br>6<br>3<br>7 |
| R10 (RESISTOR) |  | & V3<br>60VAC | 3<br>3 |
| 60 VAC |  | R10<br>12VAC | 3<br>4 |
| 12 VAC |  | 60 VAC | |
| C1(A) |  | & V3<br>R7 (BETWEEN) | 7 |

Problem B. Example 1 (continued)

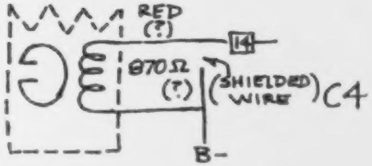
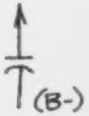
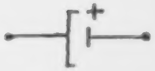
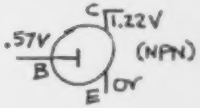
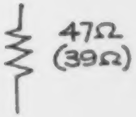
| Ref. Designator | Component Symbol | Connect to | Leads (pin) |
|---|---|---|---|
| R7 |  | V3<br>R8 | 7 |
| C1(B) |  | & R7<br>R8 | (BETWEEN) |
| R8 |  | R7<br>C1 (C) | |
| C1(C) |  | R7 | |

NOTE: ⏚ (SYMBOL) DENOTES BATTERY GROUND.

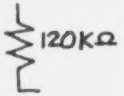
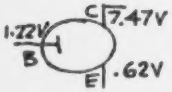
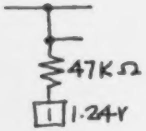
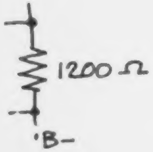
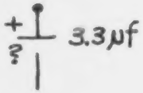
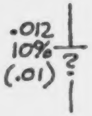
NOTE: SEE INSTRUCTOR GUIDE FOR PROBLEM SOLUTION.

**Problem B. Example 2 ("Field Notes")**

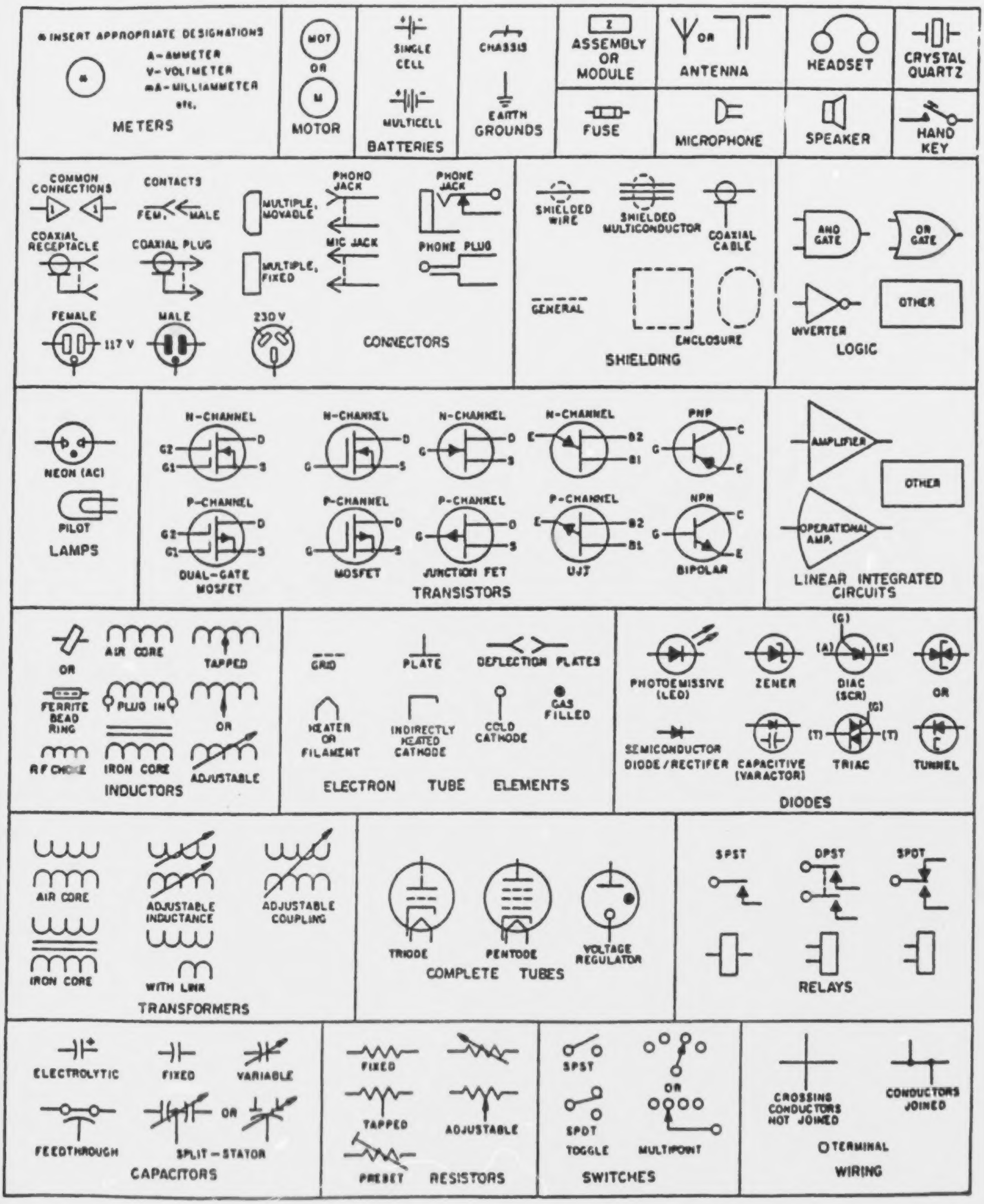
Instructions: Using the "field notes" below, and starting at the left side of your work page, arrange (sketch) the given components within an elementary schematic framework exemplified by those problems presented in Problem A. above. (Examples 1 and 2.)
Note: Some symbols are shown partial and must be completed.
#1406 (4-B) Olimpic tape player-TDK 303, TDK 305.

| Ref. Designator | Component Symbol | Connect to | Leads (pin) |
|---|---|---|---|
| RIGHT<br>(M1) |  RED<br>(?)<br>14<br>870Ω<br>(?)<br>(SHIELDED WIRE)<br>C4<br>B- | | |
| C2 |  | BETWEEN M1&C4<br>B- | |
| C4 |  | M1<br>TR2 | B |
| TR2 |  C<br>1.22V<br>.57V<br>B<br>(NPN)<br>E<br>0V | C4<br>C12<br>R2 | B<br>C<br>E |
| R2 |  | TR2<br>B- | E |

**Problem B. Example 2 (continued)**

| Ref. Designator | Component Symbol | Connect to | Leads (pin) |
|---|---|---|---|
| R13 |  | BETWEEN C4&TR2<br>& BETWEEN R10&TR4 | B<br>E |
| C12 | —?— | TR2<br>TR4 | C<br>C |
| TR4 |  C<br>7.47V<br>1.22V<br>B<br>E<br>.62V | R4<br>C12<br>R10 | B<br>C<br>E |
| R4 |  | BETWEEN C12&TR2<br>1 (CHECK POINT) | C |
| R10 |  | TR4<br>B- | E |
| C8 |  | BETWEEN R13&TR4<br>R10&B- | E |
| R6 | —?—<br>5600Ω<br>(8200Ω) | BETWEEN R2&TR2<br>C6(THRU) | E |
| C6 |  | BETWEEN C-10&TR4<br>R6 | C |

# SCHEMATIC SYMBOLS USED IN CIRCUIT DIAGRAMS


* INSERT APPROPRIATE DESIGNATIONS
A-AMMETER
V-VOLTMETER
mA-MILLIAMMETER
etc.
METERS
MOT
OR
M
MOTOR
SINGLE CELL
MULTICELL
BATTERIES
CHASSIS
EARTH
GROUNDS
ASSEMBLY OR MODULE
FUSE
OR
ANTENNA
MICROPHONE
HEADSET
SPEAKER
CRYSTAL QUARTZ
HAND KEY
COMMON CONNECTIONS
CONTACTS
FEM.
MALE
MULTIPLE, MOVABLE
MULTIPLE, FIXED
PHONO JACK
MIC JACK
PHONE JACK
PHONE PLUG
COAXIAL RECEPTACLE
COAXIAL PLUG
FEMALE
117 V
MALE
230 V
CONNECTORS
SHIELDED WIRE
SHIELDED MULTICONDUCTOR
COAXIAL CABLE
GENERAL
ENCLOSURE
SHIELDING
AND GATE
OR GATE
INVERTER
OTHER
LOGIC
NEON (AC)
PILOT
LAMPS
N-CHANNEL
P-CHANNEL
G2
G1
D
S
G
E
B2
B1
C
PNP
NPN
DUAL-GATE MOSFET
MOSFET
JUNCTION FET
UJT
BIPOLAR
TRANSISTORS
AMPLIFIER
OPERATIONAL AMP.
OTHER
LINEAR INTEGRATED CIRCUITS
OR
FERRITE BEAD RING
RF CHOKE
AIR CORE
PLUG IN
IRON CORE
TAPPED
OR
ADJUSTABLE
INDUCTORS
GRID
PLATE
DEFLECTION PLATES
HEATER OR FILAMENT
INDIRECTLY HEATED CATHODE
COLD CATHODE
GAS FILLED
ELECTRON TUBE ELEMENTS
PHOTOEMISSIVE (LED)
ZENER
(G)
(A)
(K)
DIAC (SCR)
OR
SEMICONDUCTOR DIODE/RECTIFER
CAPACITIVE (VARACTOR)
(T)
(G)
(T)
TRIAC
TUNNEL
DIODES
AIR CORE
IRON CORE
ADJUSTABLE INDUCTANCE
WITH LINK
ADJUSTABLE COUPLING
TRANSFORMERS
TRIODE
PENTODE
VOLTAGE REGULATOR
COMPLETE TUBES
SPST
DPST
SPDT
RELAYS
ELECTROLYTIC
FIXED
VARIABLE
FEEDTHROUGH
OR
SPLIT-STATOR
CAPACITORS
FIXED
TAPPED
PRESET
ADJUSTABLE
RESISTORS
SPST
SPDT
TOGGLE
OR
MULTIPOINT
SWITCHES
CROSSING CONDUCTORS NOT JOINED
CONDUCTORS JOINED
O TERMINAL
WIRING

## Table 6-1. Color Code Chart used for Determining Resistance Values

| | First Color Band | Second Color Band | Third Color Band | Fourth Color Band |
|---|---|---|---|---|
| Color Code | First Significant Figure | Second Significant Figure | Number of Zeros to Add | Tolerance |
| 0 Black | 0 | 0 | 0 | No color 20% |
| 1 Brown | 1 | 1 | 1 | Silver 10% |
| 2 Red | 2 | 2 | 2 | Gold 5% |
| 3 Orange | 3 | 3 | 3 | |
| 4 Yellow | 4 | 4 | 4 | |
| 5 Green | 5 | 5 | 5 | |
| 6 Blue | 6 | 6 | 6 | |
| 7 Violet | 7 | 7 | 7 | |
| 8 Grey | 8 | 8 | 8 | |
| 9 White | 9 | 9 | 9 | |

## COMPLIANCE STATEMENT

### TITLE VI, CIVIL RIGHTS ACT OF 1964; THE MODIFIED COURT ORDER, CIVIL ACTION 5281, FEDERAL DISTRICT COURT, EASTERN DISTRICT OF TEXAS, TYLER DIVISION

Reviews of local education agencies pertaining to compliance with Title VI Civil Rights Act of 1964 and with specific requirements of the Modified Court Order, Civil Action No. 5281, Federal District Court, Eastern District of Texas, Tyler Division are conducted periodically by staff representatives of the Texas Education Agency. These reviews cover at least the following policies and practices:

(1) acceptance policies on student transfers from other school districts;

(2) operation of school bus routes or runs on a non-segregated basis;

(3) nondiscrimination in extracurricular activities and the use of school facilities;

(4) nondiscriminatory practices in the hiring, assigning, promoting, paying, demoting, reassigning, or dismissing of faculty and staff members who work with children;

(5) enrollment and assignment of students without discrimination on the basis of race, color, or national origin;

(6) nondiscriminatory practices relating to the use of a student's first language; and

(7) evidence of published procedures for hearing complaints and grievances.

In addition to conducting reviews, the Texas Education Agency staff representatives check complaints of discrimination made by a citizen or citizens residing in a school district where it is alleged discriminatory practices have occurred or are occurring.

Where a violation of Title VI of the Civil Rights Act is found, the findings are reported to the Office for Civil Rights, Department of Health, Education and Welfare.

If there is a direct violation of the Court Order in Civil Action No. 5281 that cannot be cleared through negotiation, the sanctions required by the Court Order are applied.

### TITLE VII, CIVIL RIGHTS ACT OF 1964: EXECUTIVE ORDERS 11246 and 11375; TITLE IX 1973 EDUCATION AMENDMENTS: REHABILITATION ACT OF 1973 AS AMENDED; 1974 AMENDMENTS TO THE WAGE-HOUR LAW EXPANDING THE AGE DISCRIMINATION IN EMPLOYMENT ACT OF 1967; VIETNAM ERA VETERANS READJUSTMENT ASSISTANCE ACT OF 1972 AS AMENDED IN 1974.

It is the policy of the Texas Education Agency to comply fully with the nondiscrimination provisions of all federal and state laws and regulation by assuring that no person shall be excluded from consideration for recruitment, selection, appointment, training, promotion, retention, or any other personnel action, or be denied any benefits or participation in any programs of activities which it operates on the grounds of race, religion, color, national origin, sex, handicap, age, or veteran status (except where age, sex, or handicap constitute a bona fide occupational qualification necessary to proper and efficient administration). The Texas Education Agency makes positive efforts to employ and advance in employment all protected groups.